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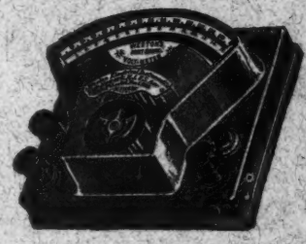

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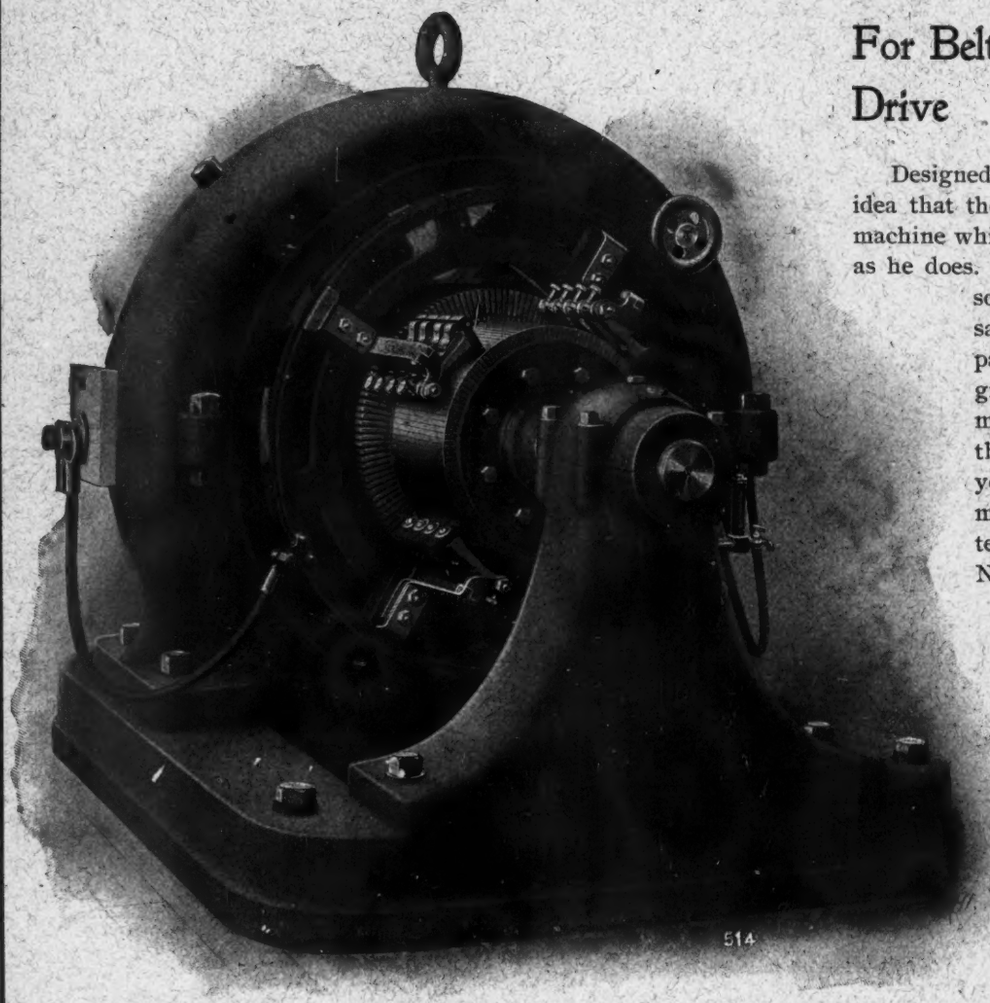

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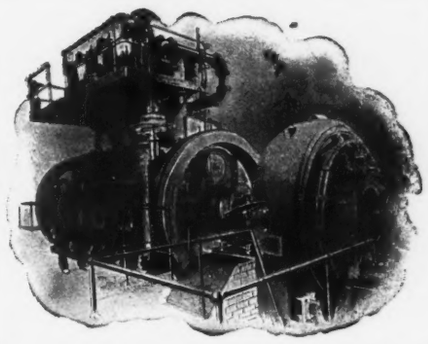

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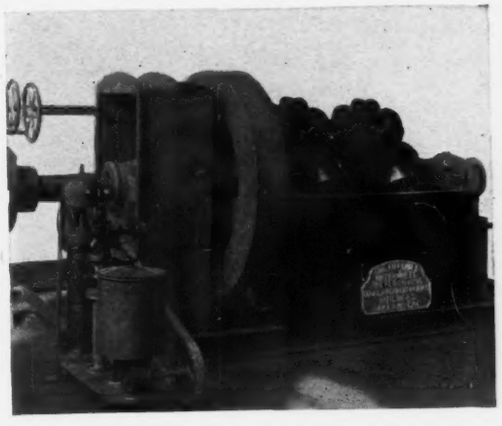

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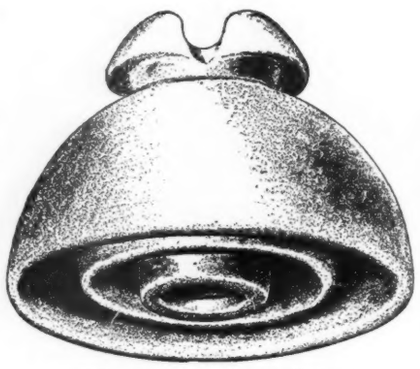

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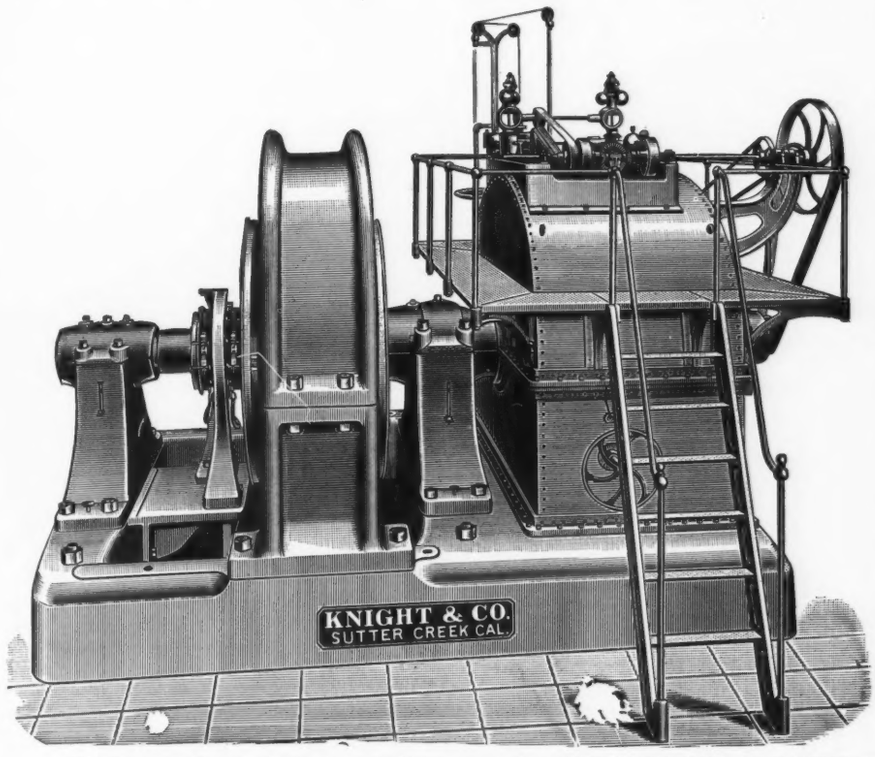

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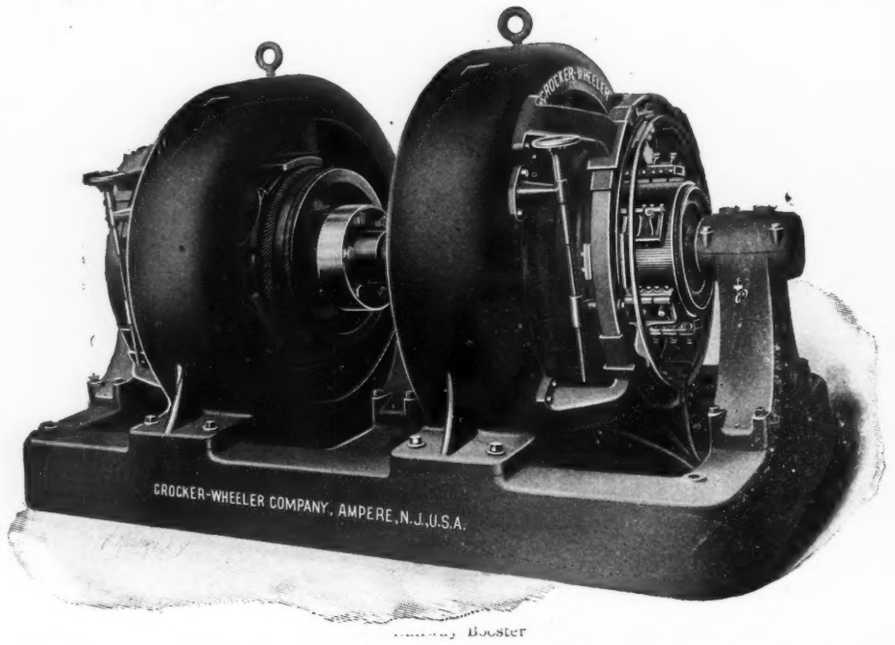

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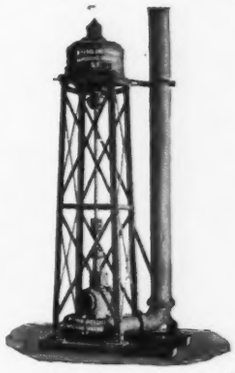

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The System of the Los Angeles Electric Company.

SOUTHERN California—land of sunshine—world-famed for its climate, its immense orange groves, beautiful flowers, numerous producing oil wells, great mining interests, enormous annual crop of tourists, three transcontinental railways and many other good things—has also the proud distinction of being classed with the pioneers in the development and advancement of electricity and its many applications, the city of Los Angeles claiming to be the first city in the world which adopted and used exclusively the electric arc lamp for municipal lighting.

On September 9, 1882, the Los Angeles city council made a contract to light the streets of the city of Los Angeles for a period of two years. The contract specified the placing of seven masts, each mast one hundred and fifty feet in height, the top of each mast to carry three three-thousand candle-power lamps; a fourth lamp was added to two of these masts, making a total of twenty-three three-thousand candle-power lamps to light up an area of about six square miles.

The Los Angeles Electric Company was then organized to carry out this contract, and a power house of moderate proportions, as shown on this page, was erected at the corner of Banning and Alameda streets. This building consisted of an engine and dynamo room 50x50 feet and a boiler house 25x25 feet, in which were placed two 54-inch by 16-foot horizontal return tubular boilers. The engines were two 10x16-inch slide valve type, two hundred revolutions per minute They were supposed to cut off automatically, but they didn't. The automatic arrangement consisted of a link movement which shortened or lengthened the travel of the slide valve, the throw of this link being controlled by a fly-ball governor. This device signally failed and was replaced by a throttling governor. The electric equipment consisted of two No. 8 Brush constant current arc light dynamos with cast-iron armatures, their respective capacities being forty 9.6-ampere arc lights and twenty-seven 15-ampere arc lights, supplying double rod Brush arc lamps. The 9.6-ampere lamps were used for commercial lighting.

FIGURE 1—THE ORIGINAL POWER HOUSE OF THE LOS ANGELES ELECTRIC COMPANY.

On the first night the lamps were lighted they demonstrated their superiority for street lighting, even over the great area they were then lighting.

The Los Angeles Electric Company, within six months after starting up, doubled its capacity, and the demand for electric light became so great as to cause the company to seek new and larger quarters. The present site, corner Palmetto and Alameda streets, was purchased, and in 1892 it moved into the power house shown in view No. 2. This power house is a solid brick structure 100 feet front by 169 feet average depth, and is composed of boiler house and engine dynamo room. The boiler room is 29x174 feet average length, and is separated from the engine room by a fire wall. It contains twelve 60-inch by 16-foot return tubular boilers, set in three batteries of four boilers each. These boilers are of the two $\frac{15}{32}$-inch sheet, butt and double strap joint type, and are mounted with independent steam drums and pipe fittings which connect with the main steam pipe line. The boiler room also contains three watertube boilers of the porcupine type, having a capacity of 200 horsepower each. Petroleum oil from the local fields is used for fuel. This oil averages 15 degrees gravity at 60 degrees Fahrenheit, carrying 5 per cent water and sediment. The oil is delivered from tank wagons into a measuring tank, and a sample of the oil is taken from each load and tested by the gasoline test for percentage of water and sediment in the oil. The oil is then pumped into a 3750-barrel storage tank, and from the storage tank the oil as required is pumped into the daily consumption tank, from which accurate measurements of the fuel consumption can be made. The oil is drawn from this tank by pumps which deliver the fuel oil to the burners at twenty pounds gage pressure. Before the oil reaches the burners it is circulated through pipes in the smoke breeching of the boilers, heating it to 120 degrees Fahrenheit. This temperature materially reduces the amount of steam used by the burner in vaporizing the oil in the furnace.

Passing into the engine-dynamo room, which is 69x160 feet average length, there are nine engines located in a line parallel to the length of the building, as shown in view No. 3. These engines consist of three cross-compound Corliss type, made respectively by the Hoover, Owens & Rentchler Corliss, St. Louis Corliss, and Lane-Bodley Corliss companies. The dimensions of each one of these engines are 18x42 inch high pressure cylinder, 34x42 inch low pressure cylinder, each running at ninety revolutions per minute a rope grooved wheel eighteen feet in diameter. There are also three 18x42 inch single cylinder Corliss condensing engines, each running a sixteen foot drive wheel at eighty-five revolutions per minute; one cross-compound Allis Corliss (14x36 inch high pressure cylinder, 26x36 inch low pressure cylinder) engine, running a drive wheel sixteen feet in diameter at ninety revolutions per minute; also one 100-horsepower tandem compound, and one 100-horsepower single cylinder Buckeye engine. These engines are all supplied with steam from one twelve-inch diameter straight line main steam pipe 142 feet long. Compensation and allowance for expansion of this main steam pipe is accomplished by

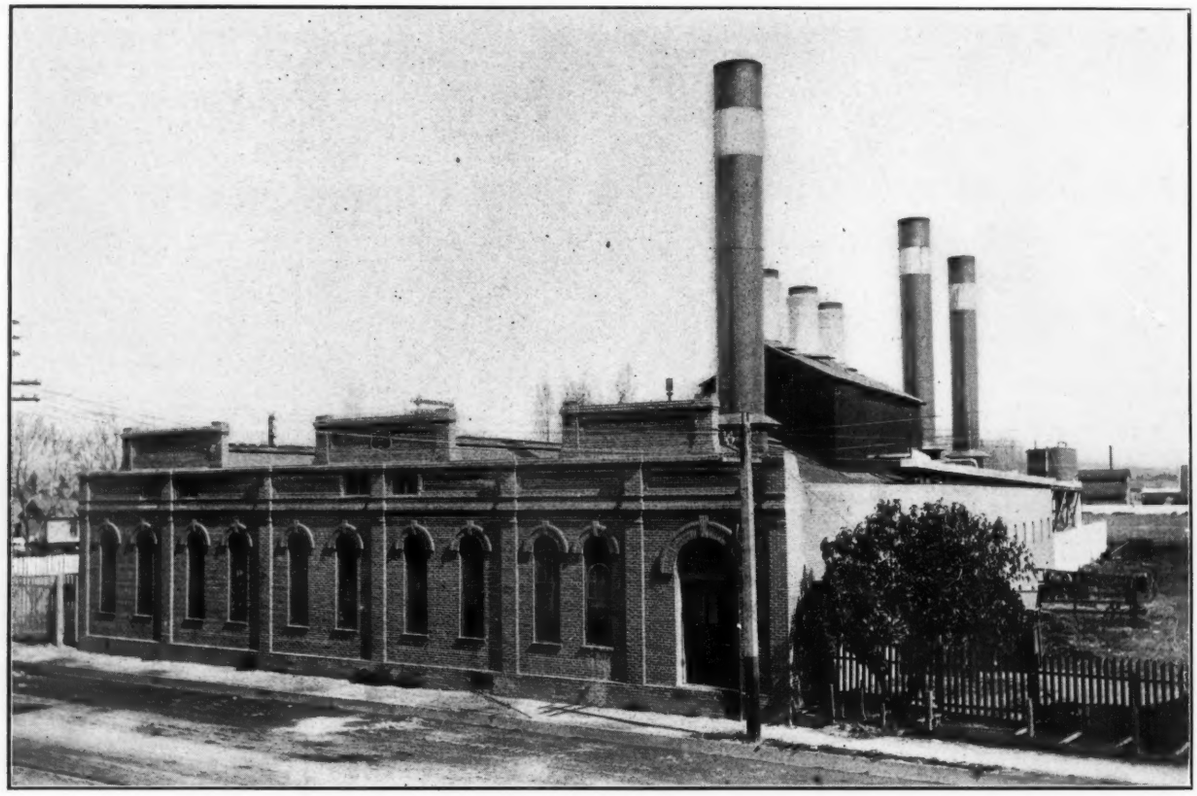


FIGURE 2.—THE PRESENT WORKS OF THE LOS ANGELES ELECTRIC COMPANY.

the use of compound curves in all the steam supply pipes from the boilers and to the engines.

The exhaust of the different engines is delivered in one main line exhaust pipe, to which are connected five surface condensers of the Wheeler Admiralty type, the circulating and air pumps being located under the condenser box. The air pumps deliver the condensed steam into a feed-water scrubber consisting of a 4x4x8-foot tank, having compartments filled with excelsior. The condensed steam in passing through the excelsior frees itself of the lubricating oils which are put in the steam cylinders. This scrubbing device solves the difficult problem of keeping the lubricating oil out of the boilers. The circulating water used in the condensers is taken from an irrigating ditch. This water passes through the condensers on its way to the irrigators, and answers the double purpose of helping to generate electricity and to grow vegetables. A sixteen-inch circulating water pipe is connected to a reservoir 74x35x6 feet in depth, and over this reservoir is placed a system of laths for cooling the circulating water. In case the water in the ditch is for any reason cut off, this system permits of the continued use of the same circulating water, as the water in dropping over the laths is broken up so fine that it readily imparts to the atmosphere the heat which it has absorbed from the exhaust steam in the condenser.

In the dynamo department there are, as shown in view 4, three 300-kilowatt single phase, 16 000 alternations at 500 revolutions per minute, 1000-volt generators, Westinghouse manufacture; one 200-kilowatt single phase, 16,000 alternations, T. H. generator; one 120-kilowatt single phase, 16,000 alternations, T. H. generator; one 120-kilowatt single phase, 16,000 alternations, Westinghouse generator; one 120-kilowatt, single phase, 16,000 alternations, National generator; two 200-kilowatt, 500-volt, direct current, Westinghouse generators; five No. 8, 60-light, 9.6-ampere Brush arc machines.

One 300-kilowatt alternating current generator and one 200-kilowatt direct current machine are coupled together and each set is driven by one of the large compound Corliss engines, which is belted direct to the generator set by twenty-one one-inch ropes. The Brush arc machines

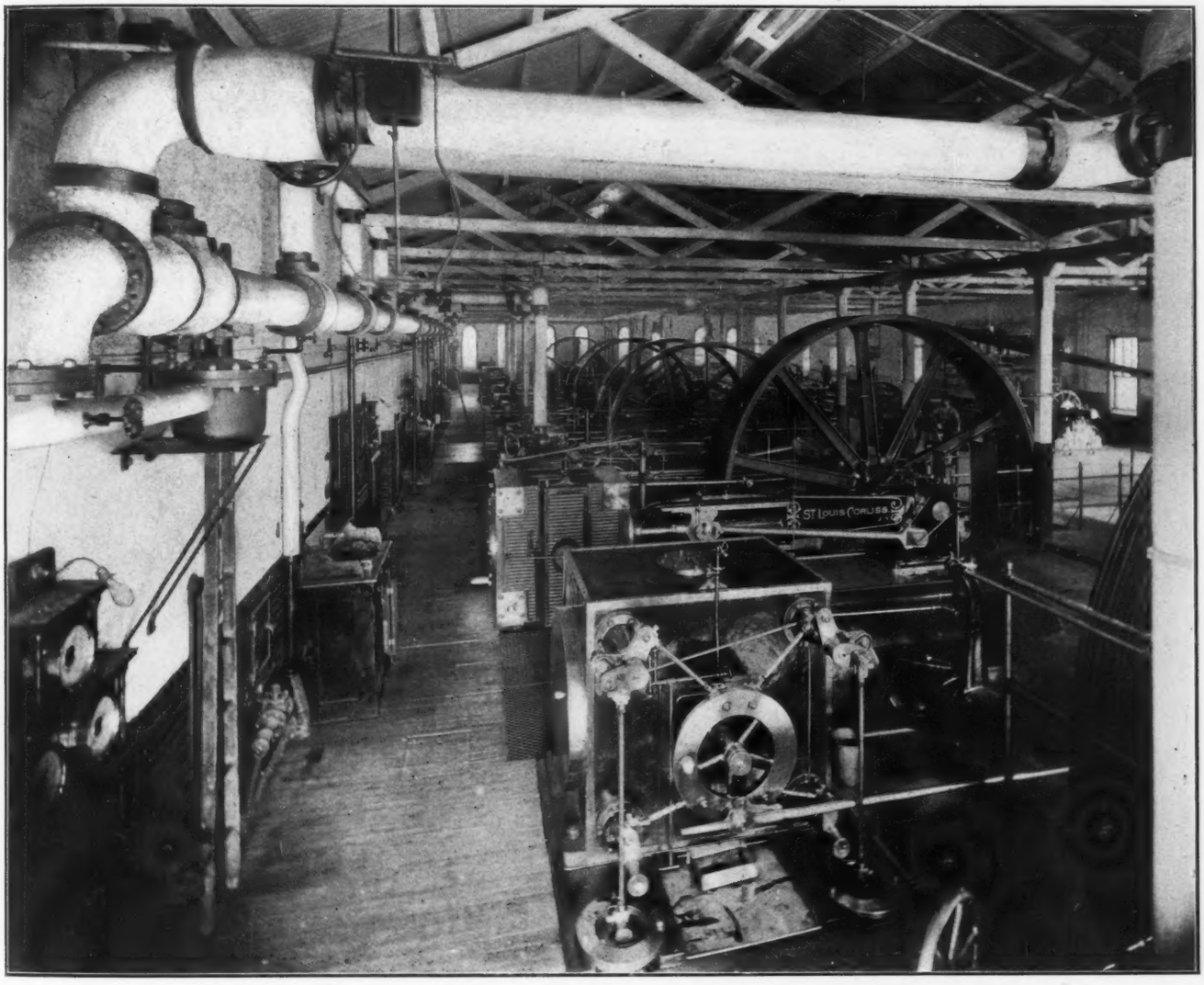


FIGURE 3.—THE ENGINE ROOM IS AN IMPOSING TYPE OF THE BELT-DRIVEN-GENERATOR SCHOOL.

are driven four in tandem direct from one of the single cylinder engines. All the wire leads between the different machines and the switchboard are carried under the floor through a conduit tunnel.

The distributing board is of the double deck, marble mounted type, as shown in view 5, in which are combined the control of the alternating current, the direct current power and arc machines (from panels operated from the floor), and the trunk lines and dynamo changing switches (operated from the upper grating).

All the electricity generated in the station is passed through recording wattmeters, giving a record of the entire output The alternating current, supplying the suburban districts, is passed through 1000x2000-volt, 100 kilowatts each, raising transformers.

The Los Angeles Electric Company's line distributing system, consisting of aerial and underground lines, is composed of alternating current lines for lighting service, 500-volt lines for power, constant current lines for commercial arc lights, and the municipal street lighting lines for the series alternating constant current inclosed arc lamps. The municipal arc lighting service is composed of nineteen separate circuits, covering the 43.27 square miles within the city's limits, and supplying current to 936 arc lamps in circuit.

The underground distributing system covers an area of one-third square miles enclosing the business district of the city. The Los Angeles Electric Company's underground conduits are composed of four three-inch fiber pipes imbedded in concrete. Service boxes with cast iron covers are placed at intervals along the conduit, from which iron service pipes are run to the building, the service wires being run into the building and distribution made therefrom. Transformer vaults are placed at street corners and middle of blocks where required, and in each vault one 25-kilowatt 1000x100-volt transformer is placed and connected to the two-wire secondary mains. These secondary mains consist of a rubber covered juted cable. The primary lines are a duplex paper insulated lead covered cable. The constant current and alternating current series wires have the same character of insulation as the primary wires. The power feeders are rubber covered juted cables. This underground system has been in use since January, 1899, and has given perfect satisfaction.

The Los Angeles Electric Company has shared its burden of the trials and tribulations which inevitably come

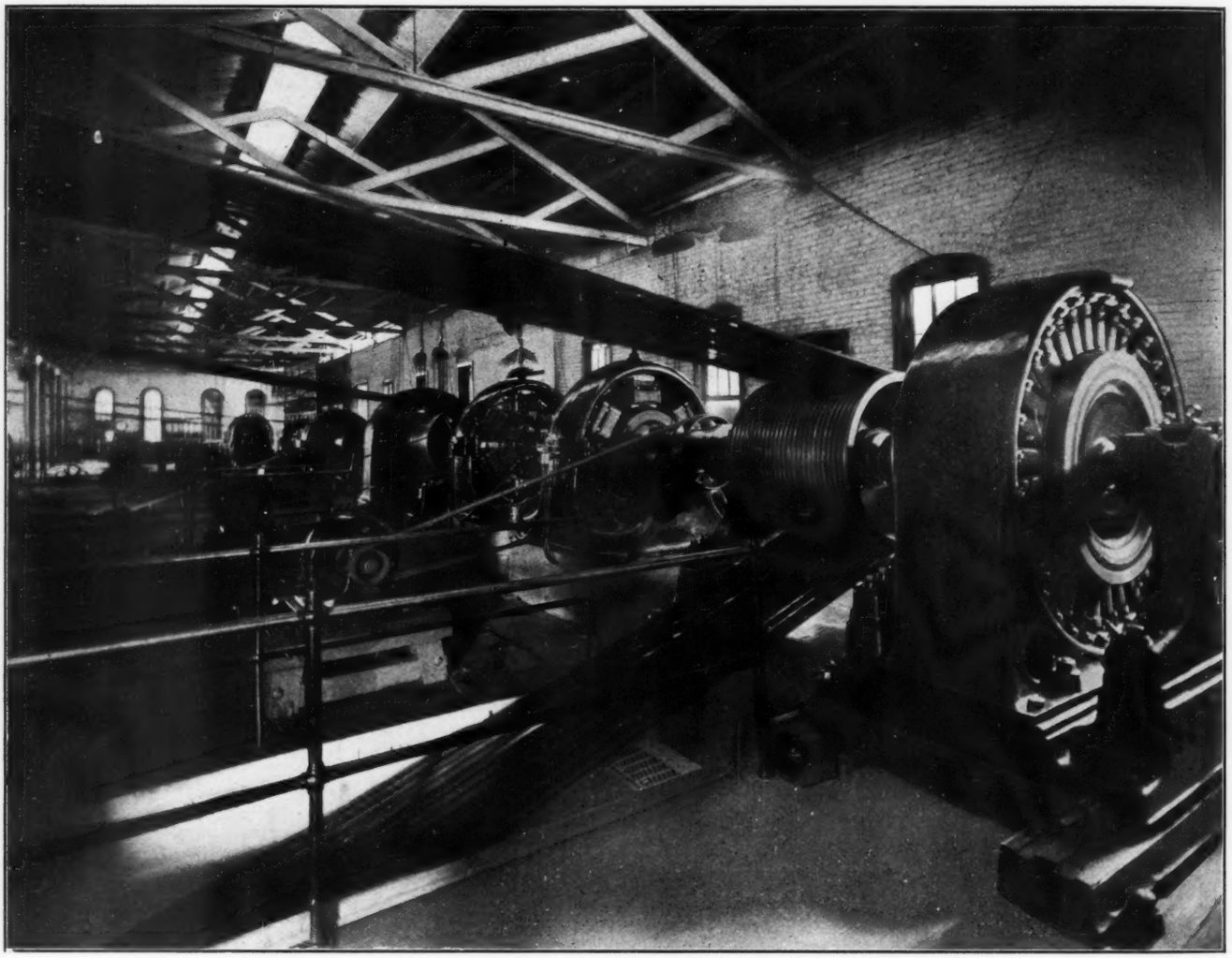


FIGURE 4.—THERE ARE FOURTEEN GENERATORS IN THE POWER HOUSE OF THE LOS ANGELES ELECTRIC COMPANY.

to the pioneer in all lines of business, and more particularly in the early electric lighting business—in the light that failed, the machines that persisted in burning out just at the peak, the engine that would not stand an overload, the belts that could not stand the strain, and the budding young electrician who would persist in making a "short" job of whatever you set him at.

ADVANTAGES OF ELECTRIC DRIVES IN FACTORIES.

IN a recent article dealing with the growing use of electric power in American cotton mills,* Mr. W. B. Smith Whaley thus sums up the advantages of the electric drive:

The convenience of distributing power in any direction by means of electric wires must appeal to those interested in the transmission of power, to say nothing of the absence in the subdivisions of the mill itself of friction clutches and other devices for disconnecting continuous lines of shafting. The absence of weight in transmission, due to belts, or ropes, heavy receiving pulleys, large shafting, expensive head gearing, etc., is an advantage, as well as the decreased first cost, and the subsequent decreased power consumption due to the lessening of friction. The absence of dirt, dust, lint and other flyings that are continually brought to the bearings of the engines and which often cause heating; the assurance that incompetent employees cannot put undue strains on the transmitting shafts by injudicious tightening of belts or ropes; and the entire absence of hygrometry on ropes or belts, which produce similar results, are factors of considerable saving in power. The transmitting wires have no moving weight, and consequently entail none of these detriments. There is no change in them except electric losses, and no necessity for belt way, belt guards or safety devices.

The motors, which are placed overhead, do not occupy any floor space, are absolutely out of reach, afford no danger to human life, and are so proportioned as to give, according to the number installed, the greatest flexibility to the plant as a whole. No special machinery is installed for lighting the plant, as the current is taken from the generator producing the power. Temporary power for any purpose, in any portion of the plant, is easily supplied by a portable motor, which is readily tapped on any power circuit in convenient reach. These, and many other advantages, from a mechanical standpoint, have been demonstrated by actual experience.

There is a saving in the friction alone of 20 per cent. The producing capacity of the machinery operated is, in actual practice, increased about 4 per cent., due to the steadiness of this method of driving over the usual method of ropes and belts, and the more uniform speed obtained throughout the plant.

*Cassier's Magazine.

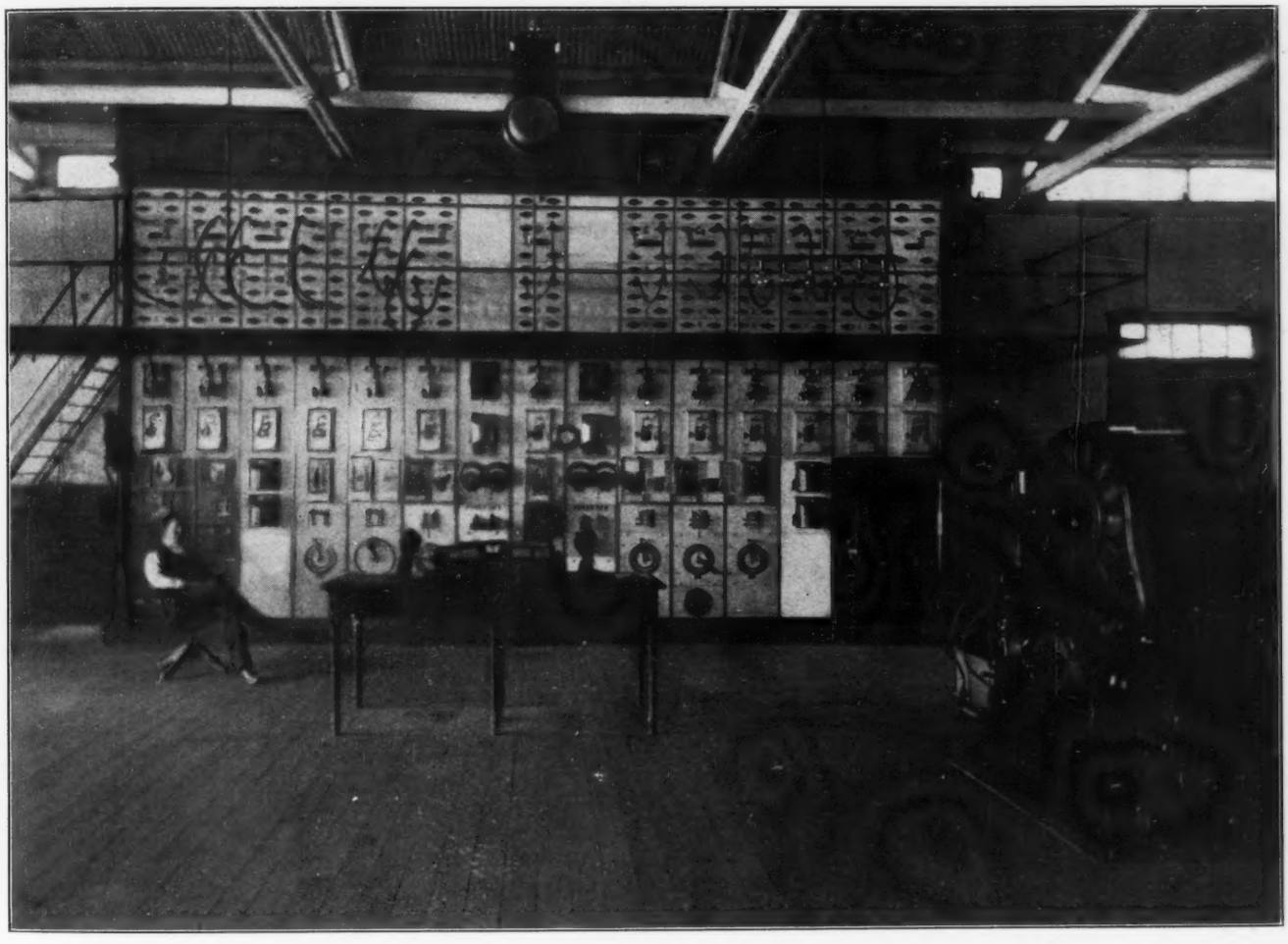


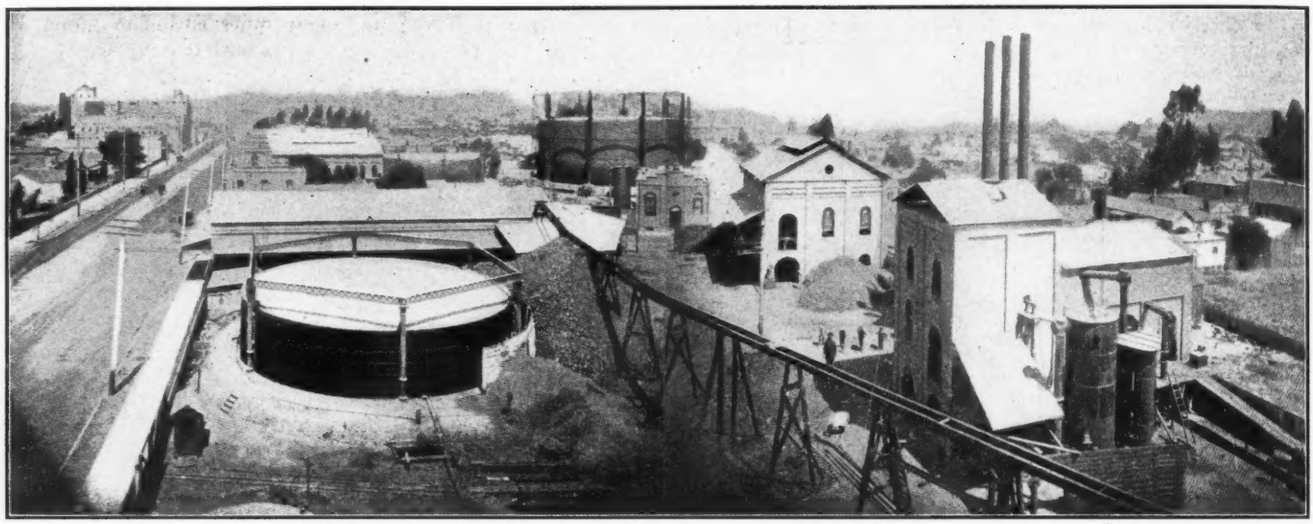
FIGURE 5.—THE DOUBLE-DECK SWITCHBOARD OF THE LOS ANGELES ELECTRIC COMPANY.

THE PER CAPITA USE OF TELEPHONES.

SAN FRANCISCO is fast beginning to lead the world in the per capita rate of telephones installed, for on December 1, 1901, it had one telephone installed to every twelve inhabitants. Statistics are available from other cities only up to January 1, 1901, on which date the figures were: St. Petersburg had one telephone to every 283 people; Vienna, one to every 120; London, one to every 111; Philadelphia, one to every 96; Paris, one to every 82; Chicago, one to every 64; New York City, one to every 49; and Stockholm had one to every 13 people.

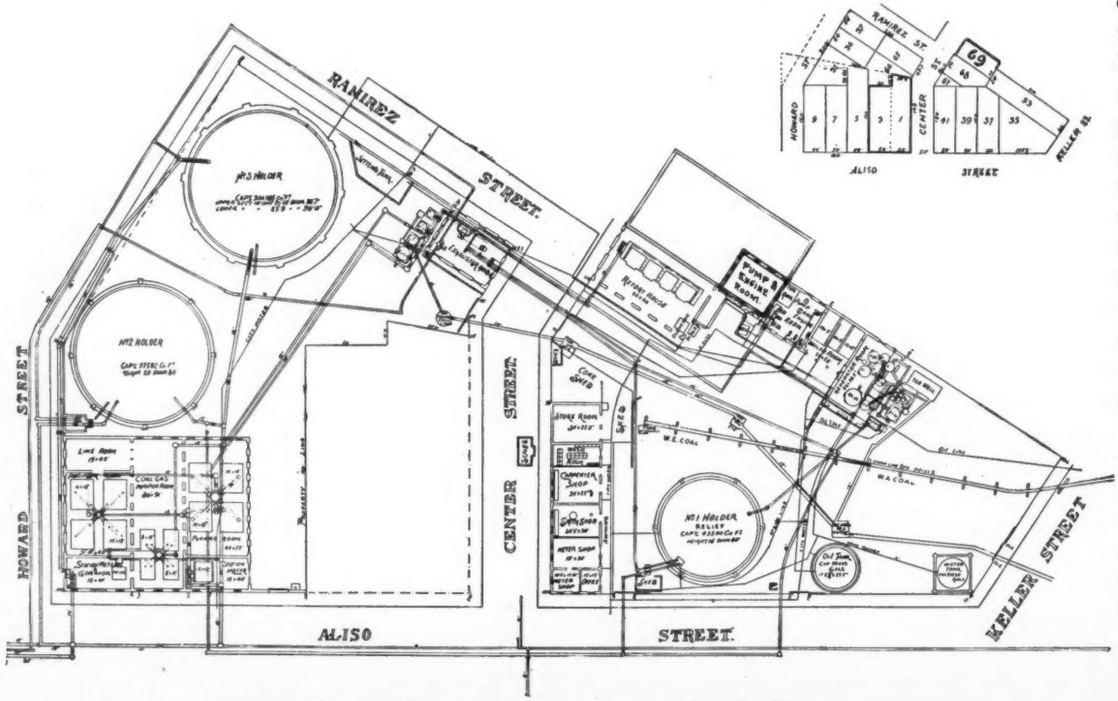
THE LOS ANGELES LIGHTING COMPANY.

GAS is generated and distributed in Los Angeles by the system of the Los Angeles Lighting Company, which was incorporated on November 14, 1889, and which soon after took over the properties of the Los Angeles Gas Company and the Lowe Gas and Electric Company. At that time the works consisted of two Springer generators, having a capacity of 300,000 cubic feet each per twenty-four hours, and five coal gas benches of five retorts each, with a capacity of 135,000 cubic feet per twenty-four hours, with holder capacity of 150,000 cubic feet, at Aliso street, and a crude oil process with generators having a capacity of 230,000 cubic feet per twenty-four hours, with holder capacity of 100,000 cubic feet, at Seventh street. The crude oil process consisted in the use of low gravity crude oil injected over the heated checker work of a generator and mingled with the hydrogen gas formed by steam passing through the heated checker work of a companion generator. This is the present day crude oil proposition, and it was abandoned by the Los Angeles Lighting Company on account of the amount of labor entailed in keeping the connections free of lampblack and because of the difficulty of fixing the gas. The seventh street works has ever since been used for gas and other storage and for the machine shop of the company. At present the gas is all manufactured at the Aliso street works, situated on Aliso street near the Los Angeles river.



A GENERAL VIEW OF THE GAS WORKS OF THE LOS ANGELES LIGHTING COMPANY.

The present works of the company consists of four water gas generators of the Springer type, with a capacity of 2,200,000 cubic feet per twenty-four hours, and four regenerative coal gas benches of nine retorts in each setting, with a capacity of 310,000 cubic feet per twenty-four hours, making a total daily capacity of 2,510,000 cubic feet. The holder capacity is 1,050,000 cubic feet. A 500,000-cubic foot three-lift holder has just been erected. This holder rests in a steel tank and has twenty-inch connections. The company's dis-

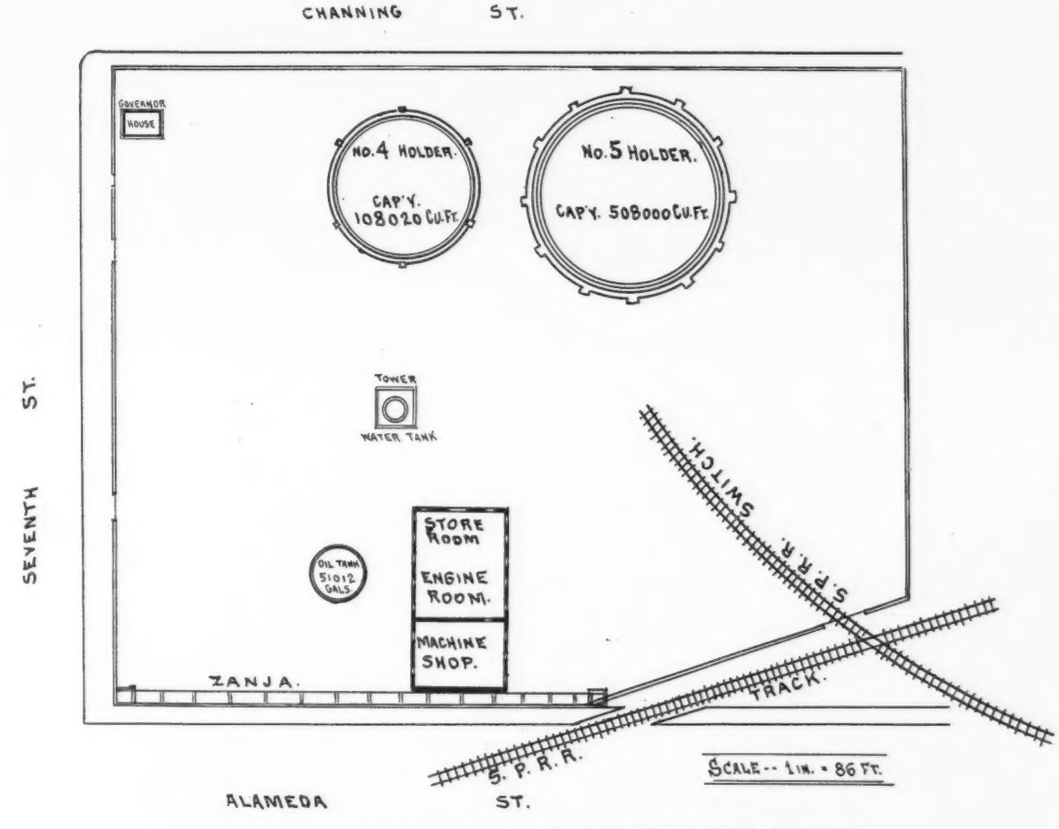


THE GAS WORKS OF THE LOS ANGELES LIGHTING COMPANY.

tributing system covers the immense area of 43.27 square miles included in the limits of the city of Los Angeles, with 160 miles of mains, and 12,534 consumers' meters in use.

Recently the company has undertaken and accomplished with perfect success the distribution of gas under high pressure, and its enterprise and courage in this undertaking is to be highly commended by the gas fraternity at large. This is believed to be the pioneer movement in the direction of taking full advantage of the opportunities of high pressure. The need for larger mains was felt as a condition for the present season, and instead of putting large sums of money into mains of large carrying capacity, after the orthodox fashion, a six-inch feeder main, about three miles in length, was laid and a compressor and gas engine connected at the end leading from the Seventh street works. The compressor is duplex, 16x18, running at 100 revolutions per minute, and is belted to a three-cylinder, vertical, eighty-five-horsepower gas engine running at 300 revolutions per minute. The gas at present is compressed to a pressure of thirteen pounds gage, and a pressure of twenty or thirty pounds is contemplated when required. High pressure meters (No. 1 Equitable Meter Company's dry meters) and regulators (No. 1 Equitable Meter Company's) are used for consumers along the line, and at the end a 6x8 Equitable Meter Company's governor is in the line. It has not, however, been found necessary to use this governor as yet. The gas leaves the governor under the present initial pressure of thirteen pounds at the works—at the end of its passage of almost three miles—at from seven to nine inches water pressure, and no house regulators are used at this pressure. The compressor is operated on the peak loads only, and the house regulators operate equally well with normal or with high pressure.

Another and smaller compressor is being operated from the Aliso street works for supplying another district, and the feeder is a two-inch pipe over a distance of 7000 feet. The initial pressure is thirteen pounds gage, and the pressure at the first consumer's meter, 7000 feet distant, is thirty inches water pressure. No regulator whatever is used, and the service is satisfactory. The company is now completing a six-inch line to the city of Pasadena, eight miles distant, and will deliver the gas under pressure of probably fifty pounds to the square inch. These



SEVENTH STREET YARD OF THE LOS ANGELES LIGHTING COMPANY.

are valuable lessons to the fraternity, and open up a wide vista of profitable engineering for other companies.

The gas appliance department is also one of the features of this company's up-to-date methods. A large storeroom is devoted to this branch of the business, and a corps of ten salesmen and five solicitors is engaged in its operation. All gas appliances are sold at cost. for cash or on the installment plan, as desired, and cottages are piped and fixtures furnished on the same terms. Fifteen wagons are in this service, which is largely the result of the solicitors' work and the low price of gas, the rate from the 1st of January being $1.00 per thousand cubic feet. The company also uses the newspapers for advertising.

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EDITORIAL.

TRANSMISSION AND FORESTRY.

One of the debts of no secondary consequence which mankind owes to posterity rests in the preservation of the forests, and if the interests vested in electric power transmission be considered, then the obligation becomes one of vital necessity, for the destruction of forests means the gradual failure of water supply, which is but another name for the certain depreciation of values invested in the hydraulic conversion and the electric transmission and distribution of the immeasurable power of the mountain water courses. Capital is reputed to be as prudent as it is timid, yet seemingly it gives as little time to furthering forest preservation as it does money to supporting such praiseworthy institutions as water and forest associations. Greater California, for instance, demands the preservation of its forests, the conservation of its winter torrents and the beneficial distribution of both the power and the water so impounded, but despite this the California Water and Forest Association languishes under unsatisfactory financial conditions, albeit that in its support lies the wisest course of procedure toward furthering the interests of the great work which it has in hand.

But the preservation of the water supply is not the only issue demanding consideration and action. The up-building of a market for power contingent upon the increase in population which is bound to come is of great concern, especially the market which will preserve the most favorable load factor for transmission systems, and in this again water supply comes in once more, for irrigation, best accomplished through pumping by electric power, can be for naught without a supply of water, first, for power purposes, and, second, for pumping purposes.

A series of water supply and irrigation papers which the United States Geological Survey has now in press, but not yet published, upon the "Wells of Southern California," by Mr. J. B. Lippincott, brings out the latter point in a very forcible manner. The region discussed is the San Bernardino Valley, in southern California, which has an area of 563 square miles and lies south and west of the Sierra Madre and San Bernardino mountains. In this portion of California, as well as elsewhere throughout the entire length of every valley within it, water is the life-blood of the land, for without it they would become semi-desert. The rain clouds from the Pacific Ocean are condensed against the 6000- to 11,000-foot elevations of the Sierra Madre and San Bernardino mountains in the winter time usually in the form of snow, which feeds the streams up to about May. Mr. Lippincott classifies the water supply as surface streams, underground water and storage reservoir water. The Santa Ana and other streams have brought down detritus and built up deltas in the valley. The winter floods gradually disappear in flowing over these deltas and, sinking down, form reservoirs of artesian water of unknown but great capacity. In addition to the winter floods, the summer flow of all the streams from San Antonio Creek to Mill Creek is diverted and used for irrigating purposes, and probably 50 per cent. of it sinks into the ground and reinforces the water plane. This large underground reservoir slopes toward Santa Ana River, the most important stream of southern California west of the Coast Range. It drains a total area above Rincon of 1657 square miles; 971 square miles of the basin are mountainous. The controlling outlet of this great underground reservoir is at Rincon, where there is a larger body of water flowing during the summer than at any other place in California south of the Tehachapi mountains, except along the Colorado. If an area of gravel of 500 square miles should be charged to a depth of 300 feet (a fair average depth to assume for this valley), its storage capacity would be 32,000,000 acre-feet of water. These figures suggest the enormous capacity of this great underground storage reservoir of San Bernardino Valley. It has been charged with waters through a long cycle of years by the floods described, hence measurements made in the summer of 1898 showed that there was almost three times more water rising in the central portion of the valley than there was entering the valley from the mountain drainage basin.

Given such a reservoir to draw from in one section alone, given hundreds of thousands of acres of land requiring only water to make it luxuriently productive, given water storage in mountain canyons that will equalize the flow of the rivers throughout the year instead of congesting them into a single month, given the energy of these rivers delivered into transmission systems for every industrial purpose, given the conditions which exist inviting immigration, given all these, yet the transmission interests, which are the ones most concerned, are apathetic in a great measure to the ultimate fate of the very fountain head of it all—forestry.

Is it right, is it prudent, is it justice even to the capital invested with transmission enterprises—that capital which it is the ambition to give perpetually a gilt-edge investment—that these points should be overlooked?

THE PART WHICH CALIFORNIA PLAYED.

In the last issue reference was made to a lecture delivered by F. A. C. Perrine, D. Sc., before the New York Electrical Society on the great power transmissions of the Pacific Coast, a lecture which, coming as it does from one who has had most intimate acquaintance with its subject, bids fair to live long in the annals of the society and of electrical engineering in the East as a veritable eye-opener to the unequalled development of transmission in the far West. Nearly all the technical press refer to Dr. Perrine's address in terms of unmeasured endorsement. The current issue of the *Electrical World and Engineer*,* for for instance, says so much in the way of acknowledgement of the part which the electrical fraternity of the Golden West has taken in the prosecution of transmission to a successful outcome, that its editorial utterance is well worthy of reproduction. It follows, therefore, in full.

Dr. Perrine's important lecture before the New York Electrical Society on the great power transmission plants of the Pacific Coast came almost like a revelation to many of the engineers who heard him. Plant after plant has been described in the technical press, but somehow isolated descriptions do not sink into the consciousness like a carefully collated discussion of the entire group. We in the East have but an imperfect idea of California conditions, and many a striking transmission plant in that region has been quietly slipped into service almost unknown even to the engineering public. Perhaps one reason for this large measure of quiet success is that our coast friends have felt the press of necessity in the matter of cheap power far more than those who dwell a thousand miles nearer the coal fields, and have gone resolutely to work to improve conditions. Consequently, with everybody working for the common good nobody raises an eyebrow at the installation of a twenty-five or thirty-five mile transmission of 15,000 or 20,000 volts—it takes two or three times both figures to really awaken interest. Here in the East even a very moderate transmission stirs up opposition with a sharp stick.

California, on the other hand, is the birthplace of real long-distance power transmission on this continent. Pomona saw the first demonstration of high-line voltage, Bodie the first serious power transmission, Redlands the beginning of polyphase transmission and distribution. Niagara, magnificent as it really is, deservedly advertised as no other transmission plant has ever been, has hitherto made less impression upon the art than these, and has not even yet developed what could fairly be called a long or high-voltage line. The vast service of the Western plants has been this, that their promoters and engineers have dared, and, daring, have accomplished what others have grown faint hearted at sight of. The result is that today power transmission for more than 200 miles at 40,000 volts is an established commercial fact. It is only ten years ago this month that the Pomona plant went into service, but 60,000 volts is in immediate sight, its feasibility having already been demonstrated. If today one should lay before any engineer personally familiar with the California work a project for sending power from Niagara to Chicago at 75,000 volts he would never wince. This great extension of the domain of electrical power transmission has been in two allied but yet distinct branches. First has been the fearless treatment of volt ages much higher than custom has hitherto sanctioned. Ferranti, abroad, was seemingly the first man who foresaw the trend of alternating current working, but his experiments, involving the even now desperate resort of high voltage underground, were under such unfavorable conditions that they checked rather than encouraged progress. The Frankfort-Lauffen experiments inspired wonder rather than confidence, and before they had led to any important results, the combination of a persistent California parson and a level-headed American engineer had turned the trick and a twenty-eight mile 10,000-volt line was an accomplished fact.

But high voltage involves more difficulties than mere insulation strength of materials. It implies as the lines grow longer a serious increase of static effects due to condenser action, and there were plenty of wiseacres, especially of the irreconcilable and fanatical wing of the sect of continuous currentites, and who solemnly put their noses down to their equations and showed to the satisfaction of any reasonable school man that long distance transmission would infallibly prove a disastrous failure. But strange to say there were some practical factors in the matter which they had forgotten, and the lines have kept stretching out to confound them and their fine drawn theories. Every dreaded bugaboo—even resonance—has proved on closer acquaintance to be a fantastic, harmless spook instead of a serious obstacle to further progress.

The two great systems which Dr. Perrine described to the society with particular care are by all odds the greatest achievements of American engineers in the art of electrical power transmission. Not only are they much longer than anything hitherto attempted, but the Standard Company at least is to operate at a voltage half again as high as any hitherto put in commercial use. Forty thousand volts, the pressure used by the Bay Counties Company at the present time, has already been demonstrated to be entirely feasible. Not only has the problem of line insulation at this pressure been pretty thoroughly worked out, but the voltage in question has been experimentally shown to be below the point at which unusual difficulties are especially to be looked for. But 60,000 volts is nearer a possible danger line, and it is worth noting that it was selected for this work by Dr. Perrine, who was Prince Poniatowski's consulting engineer, some time before even 40,000 volts had been established as a safe working voltage. The later work, and recent experiments at voltages even up to and above 100,000, have in our opinion fully justified Dr. Perrine's courageous choice as well within the limits of a safe practice. We shall be greatly surprised if this tremendous voltage gives any serious trouble in commercial use, and we venture to predict that the transmission into San Francisco will be, upon the whole, as reliable as if it were of a tenth part the length and voltage. With modern methods of construction and insulation the line has ceased to be the weak point in a transmission system. If long it must be kept under thorough inspection, but in a great power transmission system the minor distributiou circuits are ten times more likely to cause serious trouble than the main line, because in them there is less obvious need of extreme care. The extreme present range of transmission on these great California systems is 218 miles, over part of the Standard lines from the Colgate power house of the Bay Counties Company, but its success will ensure still further extensions of commercial range. It is worth noting that both these great plants are worked at sixty cycles, showing the entire futility of the extraordinary claims in behalf of very low frequency put forward a few years since. If for any purpose very low frequency is convenient or desirable it is assuredly sound policy to employ it if one wants it, but for all general purposes it is not a matter of necessity or importance even over circuits more than 200 miles long. Dr. Perrine is to be greatly congratulated not only on the admirable and striking manner in which he has described the splendid work accomplished on the coast, but for his own personal part in these most distinguished achievements—which has not been small.

*Volume XXXIX, page 188, February 1, 1902.

The Testing of Tangential Type Water Wheels.

REGARDLESS of the guarantees bought with water wheels, it is undoubtedly true that there is no hydro-electric power plant in all the great West which is in possession of at all accurate information concerning the exact performance of its prime moves in their daily duty. In general, power plant managers who are using tangential water wheels, for instance, have little, if any, idea of the efficiency which they are getting out of them, and this situation is due not only to the fact that the efficiency varies with every change in load, speed, pressure and size or form of nozzle, but also with such apparently minor features as the condition of the surface of the bucket and the position of the stream, to say nothing of the more important points embodied in the form and size of the buckets and the nature of entry and discharge. Even at the best it is no mean trick for an experienced hydraulic engineer to determine the efficiency of a water wheel under fixed conditions, so what knowledge can be expected to be had where the conditions are ever changing with respect to, say, only constantly varying load and nozzle position?

Efficiency measurements of water wheel performance, as ordinarily made, are about as reliable as measurements of the energy of alternating currents calculated without taking cognizance of the power factor of the circuit. This is not as it should be. The problem is a difficult one, yet only by the dissemination of trustworthy information concerning procedures can it be eventually worked out for each and every case. Publications like the following, then, have great value, especially in the direction indicated, despite the fact that it does not bear a recent date, and despite the fact, further, that since the tests given were made on a wheel of a now obsolete Pelton type, they cannot be applied as indicative of the performance of the present exemplary form of bucket now produced by the Pelton Water Wheel Company of San Francisco and New York.—THE EDITOR.

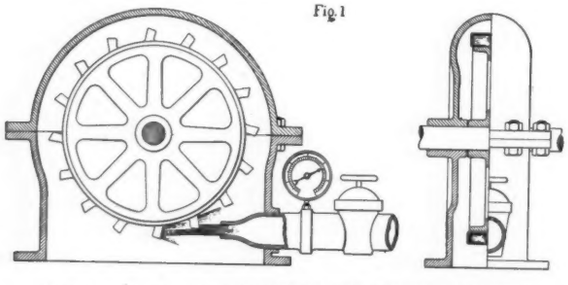
IMPULSE WATER WHEELS*

BY J. T. FARMER, MA. E.

THE development of power by means of impulse water wheels has been receiving considerable attention during the past ten years. Water power is to be met with under varying conditions and in various surroundings; and the means best adapted for the utilization of the power vary with those conditions and surroundings.

Among the means devised by man at different times before the advent of the impulse wheel for utilizing the water power that was going to waste around him, one has easily taken the foremost place, and, indeed, has, by a process of the survival of the fittest, practically ousted all other methods from a position of being worthy of serious consideration. The turbine has at the present day almost entirely taken the place of the earlier devices in use, which have either been consigned to museums as curiosities or are regarded as picturesque additions to the landscape.

Fig. 1



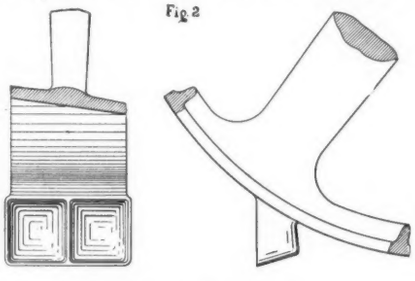
VERTICAL AND TRANSVERSE SECTION OF THE WHEEL TESTED.

The impulse water wheel probably differs as much from the various forms of turbine in construction and in action as the turbine does from an overshot or breast water wheel. The previous statement with regard to the turbine must therefore be further modified so far as it is found that the impulse motor is finding favor with those who utilize water power.

It has been said that "countless wealth is being squandered in all the torrents and water courses of the world." But it might be added that unless the proper means are taken for its utilization that wealth of energy avails little more to man than that of the tides in Jupiter.

It seems at first sight a very simple matter to place a wheel in position to take up the energy of water; but in practice that arrangement is generally found to involve more or less costly construction in the way of dams, basins, canals, flumes and even tunnels. This is particularly the case where the use of turbines is contemplated, and this consideration is frequently sufficient to annihilate the expediency of thus attempting to utilize a known and otherwise available source of power.

Fig. 2



THE FORM OF BUCKET TESTED.

These adverse conditions are forcibly illustrated in the mountainous districts of the North American Continent. Water power is there in abundance, but it is that of mountain torrents; as a rule inconsiderable in volume of water, but, on account of the configuration of the country, affording large heads. The latter circumstance makes any constructive work very costly, and in most instances would put the use of an ordinary turbine out of the question.

It was from such causes that the Western States became the birth place of that system of water power of which the essential feature is an impulse water wheel. The simplification made possible in this system is that of the substitution of a pipe and nozzle of insignificant dimensions for the massive head race and wheel pit associated with the use of a turbine.

The first impulse wheels brought into use were of the very crudest description; with the increasing use of the system, however, came the development which attends every invention which has a large field of usefulness open to it. The impulse wheel of the present day ranks as fairly efficient among the various means of utilizing natural energy.

At this stage it becomes a question to what extent it may be desirable to employ the impulse wheel outside the conditions under which it first sprang into existence. This problem is specially interesting in a country where there is an abundance of water power, and at a time when the utilization of water power is assuming the place of one of the most important engineering questions of the day. The object of this paper is to record the results of some experimental research on this subject and also to discuss the question by the light of those results and from other considerations.

*A Paper read before the Canadian Society of Civil Engineers, January 20, 1898

The history of the development of the impulse water wheel may advantageously be sketched briefly. The first wheels of this class were simply provided with flat projections on the rim of the wheel, and the jet was arranged to impinge normally on these flat surfaces. This was what was known as the hurdy-gurdy. It can easily be shown from theoretical considerations that the ideal efficiency of such a wheel is 50 per cent., but it is probable that most of those in use did not give a greater efficiency than from 20 to 30 per cent.

The first notable improvement was that of substituting hollow cups for the flat vanes, so that the jet struck the interior part of the cup and was deflected back again until it left the vane, traveling, with respect to the vane, in almost the opposite direction to that in which it was traveling before impact, as shown in figure 3. This reformation at once largely increased the efficiency, but in practice the efficiency was still far from what it theoretically might be.

The next modification was that of so curving the surface of the cup that the jet might follow the surface with very little deviation at the first point of contact. Thus, some wheels are formed with a conical projection in the interior of the cup at the point where the jet strikes the surface, so that the water on striking may begin

Fig. 3

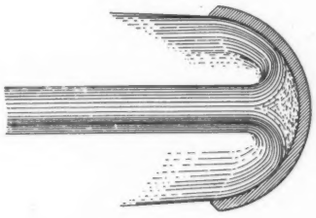
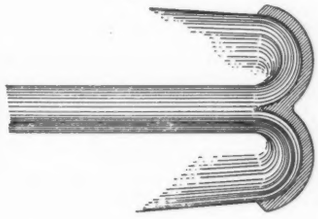


Fig. 4



to pass along the generating lines of the cone, and may gradually be deflected further to follow the curved sides of the interior of the vane. This formation is illustrated in figure 4. The more common construction is to place a wedge-shaped projection across the interior of the cup or vane. This modification was introduced about 1880. It may be seen in the bucket illustrated in figure 2. The function of the wedge is two-fold.

(1) To prevent the heaping of dead water upon the vane during its passage through the arc of action, or the part of its path in which the vane receives the jet of water.

(2) To give the diverted streams a direction of motion which will finally carry them clear of the wheel.

In a bucket unprovided with any conical or wedge-shaped projection, there is no sudden angular deflection of the water. Some of the water is heaped upon the flat surface upon which the jet is impinging, thereby forming a curved surface over which the following water is deflected, as shown in figure 3. With a stationary vane on which the stream is continuously playing, the loss of force due to this cause is very slight. When, however, the impact is taking place intermittently on a moving vane, the dead water is discharged after very inefficient action at the end of every short period of action, and the total loss in effective work may be considerable. This loss is reduced by placing a solid projection in the bucket, which takes the place of that formed by the water and leaves all the water free to be deflected in the most efficient manner. See figure 4.

As regards the second function of the wedge, it is well known that when a stream of water strikes normally upon a surface it is deflected equally in all directions. This is illustrated in the wheel bucket, of which two views are shown in figure 5. The same action takes place when the stream strikes centrally upon the apex of a cone. This is undesirable in the case of the vane of a water wheel, as the water which is deflected towards the center of the wheel gets into position to strike the back of the following vane, thus opposing the useful effect of the action. When the jet strikes a wedge, as in figure 6, it is cut into two portions, which are deflected away from one another in a plane perpendicular to the cutting edge of the wedge. In a wheel this motion causes the water to be discharged at each side of the wheel where it is free from all liability to interfere with any following parts of the wheel.

Numerous modifications of the form of the curved surfaces of the buckets have been brought out at different times by inventors

Fig. 5

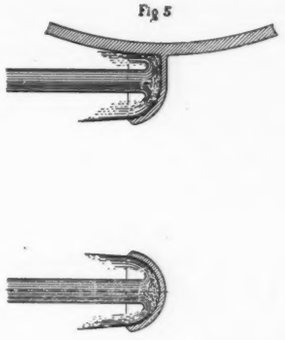
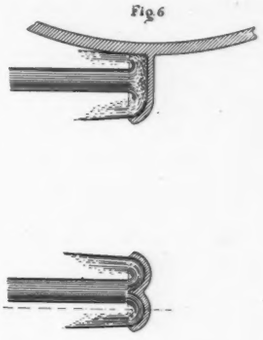


Fig. 6



with a view of modifying the passage of the water over the vane in some particular, but it is not necessary to describe them more particularly.

Of the impulse wheels in use at the present day the best known is probably the Pelton water wheel. These wheels are made in sizes varying from six inches to six feet in diameter, according to the head of water available and the velocity required. These wheels have been applied under heads ranging up to 1700 feet, and, as has been said, there is no doubt that under such conditions the highest efficiency is realized. On the other hand, there are said to be instances in which Pelton wheels are running with good results under heads of from fifty to seventy-five feet. The writer recently made a series of tests on a small wheel of this class, catalogued as the Pelton Motor No. 3. This wheel is approximately eighteen inches in diameter, and the weight of the whole machine is given as 320 pounds. Two elevations of this motor are given in figure 1.

The tests were made in the hydraulic laboratory of McGill University, and a brief description of the methods employed will be given. It was impossible to make tests with heads as high as some of those under which these motors run. The maximum head employed was that afforded by the city supply from the high level reservoir, which gives a pressure of 125 pounds per square inch in the laboratory, equivalent to a head of 290 feet. Lower pressures were also obtained by throttling the supply from the same source.

These trials will give an idea of what may be expected of this type of motor when used under ordinary heads of from 100 to 300 feet. In many districts these are as large heads as are commonly met with. Also, where it is proposed to take power from a water works system, the pressure under which water is supplied would rarely exceed 125 pounds per square inch.

In the present series of trials the wheel tested was small compared with many in use; the effective work done did not in any case exceed seven horsepower. There is no doubt that with a machine designed on a larger scale, as with larger heads, the efficiency would show some increase over the values found in the present case.

The results obtained in these experiments are offered as bearing directly on the question of the utilization of this system for small amounts of power under the conditions usually met with in districts outside those referred to as abounding in very high falls of water. With reason and judgment the general conclusions arrived at by the consideration of these results may be extended to cases where the machinery and the generation of power is on a larger scale.

For the purposes of trial the wheel was set up as received from the makers and the auxiliary apparatus was fitted in accordance with their instructions. The water, after passing through the valve which was used to regulate the pressure, was led along a

length of two and one-half inch pipe straight for eight or ten feet before reaching the nozzle. A Bourdon gauge was fitted on the supply pipe less than one foot from the mouth of the nozzle tip. This gauge was arranged on a pressure chamber enveloping the pipe and communicating with the interior through a series of small holes. Before being used the gauge was calibrated by means of a gauge tester. In the experiments the pressure in the pipe of course varied slightly. The pressure was read at intervals of one or two minutes, and the mean value during the whole trial was accepted as the pressure under which the flow took place. The extreme variation of the pressure was about one pound per square inch.

Three different sized nozzle tips were supplied with the wheel. These nozzles tapered gradually on the inside from the diameter of the supply pipe to that of the actual orifice. The outlet diameters were; .5277″ .6307″ .7532″

Sets of trials were made using the largest and smallest of these nozzle tips, the largest giving the more satisfactory results.

The water was discharged from the motor into a flume beneath, whence it ran into measuring tanks, and all the water used was thus actually measured. For the purposes of these trials two tanks were used, each of the capacity of 1000 gallons: these had both been previously calibrated.

The power given by the wheel was estimated by means of an absorption brake and a revolution counter.

The shaft was provided with an eighteen-inch diameter brake wheel of special design, and the power was taken off this. In the earlier trials the brake consisted of one or more cords embracing a suitable arc of the periphery of the brake wheel, and having spring balances attached to the tight and slack ends to indicate the corresponding tensions in the cord. As the power varied slightly all the time, both readings were taken at intervals of one or two minutes, and the means used in calculating the final result of the trial. Later a direct reading self-adjusting brake designed by Mr. Withycombe was substituted for the cords and spring balances with very satisfactory results.

An ordinary revolution counter was used, but arranged to be thrown in and out of engagement with the shaft at the beginning and end of each trial. The necessary readings could thus be made at leisure, insuring greater accuracy.

In addition to the revolution counter a tachometer was connected to the shaft. This served as a guide when adjusting the load on the brake wheel previous to a trial to give a desired speed of running. It also served to indicate any considerable departure from the intended speed which might take place during a trial, and which would vitiate the accuracy of the calculated results.

Before passing to the examination of the experimental results of the trials, it may be well to make a brief theoretical analysis of the subject.

The elementary theory of an impulse wheel is very simple—so simple, indeed, that no attempt seems to have been made to consider to what extent known and observable phenomena may modify theoretical calculations; but rather the elementary theoretical result is generally taken as the last word which can be said on the subject from a theoretical point of view.

In the following investigation the efficiency is deduced from a consideration of the circumstances, as far as they can be mathematically expressed, under which the mechanical action takes place.

In the elementary theory of the impulse water wheel the assumptions generally made are substantially as follows:

1. That the jet has the theoretical velocity due to the available head of water.

2. That the jet strikes the vane centrally and tangentially to the wheel.

3. That the jet passes over the surface of the vane without any loss of relative velocity.

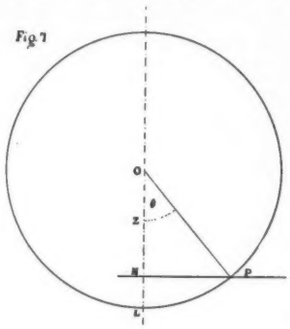
4. That the vane is so formed as to turn the stream through an angle of 180 degrees completely back on itself.

In all these particulars there are some modifications which can be more or less exactly stated:

(*a*) The velocity of the impinging jet is reduced in the ratio of a coefficient of velocity depending on the pipe line and nozzle.

(*b*) Instead of striking the vane tangentially the jet generally, as in the case particularly alluded to, strikes at a point nearer to the nozzle. Thus, suppose a horizontal jet is applied underneath a wheel. If O in figure 7 be the center of the wheel and L its lowest point, the jet strikes at P, where $L\,O\,P$ makes an angle θ say. Of course the water begins to play on the vane before it reaches P, and continues for a short space afterwards until the stream is cut off by the next approaching vane; but P may be taken as a mean position.

Fig 7



The wedges of the vanes then are formed normal to the jet at this point instead of being radial to the wheel. This involves their being inclined at an angle θ to the radius of the wheel.

(*c*) The force of impact is reduced owing to the velocity lost by the water in passing over the surface of the vane. Some previous experiments on this subject afford data which will be used in approximating to the loss due to this cause.

(*d*) It is impossible, practically, to turn the water completely back on itself on account of the reaction which would take effect on the back of the succeeding vane.

Let u be the resolved velocity of the vane at P in the direction of motion of the jet.

v that of the jet.

The water strikes the vane with relative velocity $(v-u)$ and leaves it with relative velocity $c_w\,(v-u)$, where c_w is the ratio of final to initial relative velocities.

The force exerted on the vane in the direction of motion of the water is equivalent to the momentum of water destroyed per unit time, which is:

$$\frac{m}{g}\left\{(v-u)-c_w(v-u)\cos.\,\delta\right\}$$

where δ is the angle of deflection of the water

$$\therefore F=\frac{m}{g}(v-u)(1-c_w\cos\delta)$$

Now $u=O\,P\,.\,\omega\,.\cos\theta$.

ω being the angular velocity of the wheel.

If the line of the jet cuts $O\,L$ in N, and $O\,N$ be called z,

$$\frac{O\,N}{O\,P}=\cos\theta$$

$$\therefore\ O\,P=\frac{z}{\cos\theta}$$

$$\therefore\ u=\frac{z}{\cos\theta}\ \omega\,.\cos\theta$$

$$=z\,\omega$$

$$\therefore F=\frac{m}{g}(v-z\omega)(1-c_w\cos\delta)$$

The moment of this force about the center of the wheel is

$$Fz=\frac{mz}{g}(v-z\omega)(1-c_w\cos\delta)$$

which is constant.

The work done per second is

$$F\,z\,\omega$$

$$=\frac{m\,z\,\omega}{g}(v-z\,\omega)(1-c_w\cos\delta)$$

The energy available per second is mh,

h being the available head of water. The efficiency therefore is

$$\eta=\frac{z\omega}{gh}(v-z\omega)(1-c_w\cos\delta).$$

If N be the number of revolutions per minute

$$\frac{N}{60} = \frac{\omega}{2\pi}$$

$$\therefore \eta = \frac{2\pi N z}{60gh}\left(v - \frac{2\pi N z}{60}\right)(1 - c_w \cos\delta) \text{ (I).}$$

In calculating the value of v to be inserted in this expression it must be remembered that the velocity of the issuing jet is less than that theoretically due to the head.

In practice there will be a reduction of velocity due to two causes:

(1) Resistance of pipe line.

(2) Loss in discharge from the nozzle.

If l be the length of pipe,

d the diameter,

Then the loss h_1 due to pipe friction is calculable by the well-known formula

$$h_1 = 4f\frac{l}{d}\frac{V^2}{2g}$$

V being the velocity of the water in the pipe and f the coefficient of frictional resistance of pipes.

If A_1 a be the areas of the pipe and nozzle respectively,

$$A_1 V = av$$

$$\therefore h_1 = 4f\frac{l}{d}\frac{a^2}{A_1^2}\frac{v^2}{2g}.$$

Other losses due to bends, etc., can be considered included in a coefficient K, which would have to be derived from consideration of the special circumstances in every case. This would make the total loss of head in the pipe line.

$$h_1 + h_2 = \left(4f\frac{l}{d}\frac{a^2}{A_1^2} + K\right)\frac{v^2}{2g}$$

The remainder of the available head is spent in producing the velocity v, and part is absorbed in the resistance of the nozzle. If the nozzle offered no resistance the velocity would be increased in the ratio of $1 : c_v$, and therefore the velocity equivalent to the remaining head is

$$\frac{v}{c_v}.$$

The energy remaining is, therefore,

$$\frac{v^2}{c_v^2\, 2g}$$

$$\therefore h = h_1 + h_2 + \frac{v^2}{c_v^2\, 2g}$$

$$= \left(\frac{1}{c_v^2} + 4f\frac{l}{d}\frac{a^2}{A_1^2} + K\right)\frac{v^2}{2g}$$

Numerical values inserted in this formula will give

$$h = (1.06 + .026\frac{l}{d}\frac{a^2}{A_1^2} + K)\frac{v^2}{2g}$$

The results given by this formula would only approximate more or less closely to the actual state of affairs, which would best be determined by actual measurement of the pressure close to the nozzle by means of a gauge, when the conditions of flow are those actually occurring in practice.

In the trials under discussion the heads given are those measured close to the point of discharge, so that no loss due to the pipe line need be considered. The only loss of velocity is that which occurs in the discharge from the nozzle, and the value of v therefore is calculated from the formula

$$v = c_v\sqrt{2gh}$$

where c_v is the coefficient of velocity for the nozzle used.

In the nozzles used in the experiments the stream issued from a parallel throat, and consequently there would be no appreciable contraction of the jet. On this consideration it is reasonable to attribute all the deficit in discharge to the loss in velocity or

$$c_v = c_d.$$

The coefficients of discharge were determined for these nozzles for heads up to twenty feet, above which point the variation becomes very slight. The results obtained therefore give an approximation to the true velocity of the jet.

In addition to these determinations the coefficient of discharge was calculated from the data afforded by each of the trials. These coefficients agreed very closely with those obtained directly in the case of the three-quarter inch nozzle. The mean values were .972 and .980 respectively.

The discrepancy is not surprising when it is considered that in the former case the outflow was from the end of a long pipe, while in the latter it was from a large body of water at rest.

The discrepancy is more marked in the case of the nozzle one-half inch in diameter, where the two values are .909 and .976. It is suggested that this difference is due to the fact that the interior of this nozzle was covered with rust at the time of its being used in the water wheel, as it had been in place for some time. The coating of oxide on the interior would diminish the actual area of outlet, so that the coefficient would appear to be smaller than it actually was. In addition to this there can be no doubt that the rough surface of the oxide would diminish the velocity of the outflowing water; this may be partly the reason why the trials with the one-half inch nozzle show a smaller efficiency than those made with the three-quarter inch nozzle.

If this explanation is correct, it would point to the desirability of having the interior surfaces of the nozzle tips clean and free from rust. To accomplish this, it would probably be worth while to have detachable nozzle tips made of brass or some other metal not so liable to be acted upon as iron in the presence of moisture. It would also be advisable for the user to periodically take out and clean the nozzle tip, especially if made of cast or wrought iron.

With a dirty nozzle there is a direct loss of efficiency corresponding to whatever loss of velocity is caused by the rough surface of the nozzle. More than this, there is a diminution in the area of the outlet, and therefore in the discharge, with the result that the power developed by the motor falls off. This may become a serious consideration if the motor is not much more than equal to the demands usually made upon it.

The particular values will now be inserted in the expression for the efficiency.

Pressures = 75 and 100 pounds per square inch.

Corresponding heads = 175 and 235 feet.

v = 103.1 and 119.6 feet per second.

z = .666 feet.

δ = 170 degrees.

$\cos\delta$ = .9848.

The value of c_w can be deduced, as mentioned previously, from an expression derived from a series of experiments on vanes of this description,

$$r = \frac{w}{v_o} = .0266\frac{A}{a}\frac{1}{v_o^{.3}}$$

where w is loss of velocity, v_o the mean velocity of the water, a the sectional area of the jet and A the wetted area of the vane.

$c_w = 1 - r$ approximately.

The ratio $\frac{A}{a}$ is about 6.6

whence $r = .176\frac{1}{v_o^{.3}}$

The quantity expressed by v_o here is the mean velocity with which the water passes over the surface of a bucket and may be taken as

$$\left(v - \frac{2\pi N z}{60}\right)$$

in expression (I).

Substituting values for the different conditions under which the wheel is run, the following table of values of c_w can be deduced:

TABLE I.

N	h = 175 feet	h = 235 feet
300	.953	.955
400	.952	.954
500	.950	.953
600	.948	.952
700	.946	.951
800	.944	.949
900	.941	.947
1000	.937	.945

These values lead to values of the factor $(1-C_v \cos \delta)$ as given in the following table:

TABLE II.

N	h=175 feet	h=235 feet
300	1.939	1.940
400	1.938	1.940
500	1.936	1.939
600	1.934	1.938
700	1.932	1 937
800	1.930	1.935
900	1.927	1.933
1000	1.923	1.931

The following values are thus obtained for the theoretical efficiency of the wheel with a three-quarter inch diameter nozzle:

TABLE III.

N	h=175 feet	h=235 feet
300	59.3	53.0
400	72.3	65.7
500	81.8	75.8
600	88.0	83.4
700	90.9	88.5
800	90.3	91.0
900	86.6	91.2
1000	79.4	88.8
	max. 91.1 @ 738	max. 91.5 @ 857

The differences between these calculated values and the actual values obtained are exhibited in Table IV. These results are illustrated graphically in figures 16 and 17.

TABLE IV.

N	h=175 feet			h=235 feet		
	Mathem.	Actual	Diff.	Mathem.	Actual	Diff.
300	59.3	....	....	53.0	....	....
400	72.3	58.4	13.9	65.7	52.5	13.2
500	81 8	64.8	17.0	75.8	59.3	16.5
600	88.0	68.2	19.8	83 4	65.0	18.4
700	90.9	69.2	21.7	88.5	69.5	19.0
800	90.3	66.2	24.1	91.0	70.0	21 0
900	86.6	....	....	91.2	66.2	25.0
1000	79.4	....	....	88.8	....	....

From this last table it is apparent that there is still a waste of from 15 to 25 per cent. of the original energy of the water which has not been accounted for. The loss due to friction of bearings would be small in a simple machine of this sort, and the greater part of the 15 to 25 per cent. loss must be due to some departure in practice of the phenomena of action from those assumed.

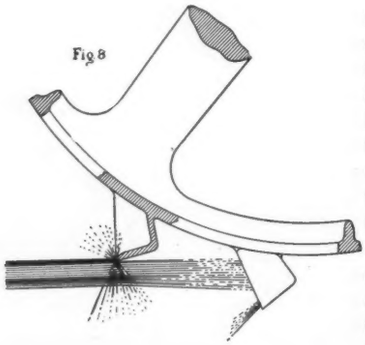


Fig. 8

It is suggested that the loss arises wholly or in part from the imperfect action of the vanes or buckets in turning back the water. It will be remembered that one of the functions of the wedge was described to be to cause the water to be discharged to the side of the wheel. A little consideration, however, will show that during a part of the period of action the wedge does not perform this function.

When the vane begins to intercept the jet, as in figure 8, it is the outer lip or scoop which first comes in contact with the jet. The small amount of water which strikes the blunt edge of this outer lip is scattered, and this only gives up a proportion of its energy to the wheel. More than this, it probably causes considerable disturbance and consequent loss of energy in the rest of the stream.

As the vane passes further into the path of the jet, as represented in figure 9, the water strikes on the interior curved surface of the outside scoop portion of the bucket on each side of the outer end of the wedge. The curve of the bucket at this point is such that the water is mainly deflected in an inward and backward curve in the plane of the wheel, so that it emerges from the vane surface in a plane tangential to the wheel rim; it proceeds in the same direction until it strikes the back of the following vane, producing upon it a force of impact opposite to the direction of motion of the wheel.

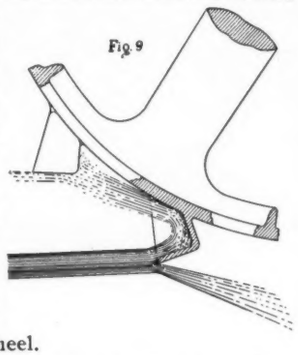


Fig. 9

As the wheel moves into such position that the jet plays upon the central portion of the wedge, the stream is deflected to each side in a plane parallel to the axis of the wheel; and it is then and only then that the conditions of action assumed are approximately fulfilled. This position is shown in figure 10.

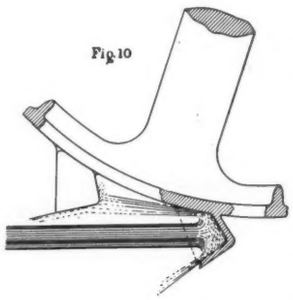


Fig. 10

It may be estimated that the action of the water is not what it is assumed to be while the vane moves over from one-fifth to one-third of the total arc of action. During this interval the action of the water is more or less inefficient.

It will be noticed that the deficit of the actual from the calculated efficiency increases steadily as the speed is increased. It is suggested that this may be attributed to two causes.

(1) The best effect of the impact occurs when the sharpe edge of the wedge is perpendicular to the line of the impinging jet. This condition only occurs at one point in the arc of action. At all other points the position of the edge of the wedge departs more or less from the perpendicular position, as in figure 11, and the deflection does not take place in the manner assumed with the consequence that the efficiency of the impact is more or less impaired. The higher the speed of the wheel the greater is the arc of action, and consequently the greater will be the departure of the cutting edge of the wedge from perpendicularity to the line of the jet. This would mean that the loss of efficiency of the impact is less when the arc of action is smaller, or the speed small, and that the loss of efficiency increases as the arc of action increases or as the speed is increased.

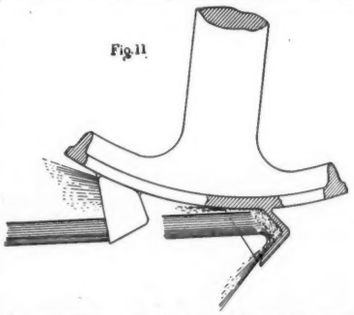


Fig. 11

(2) It was pointed out how the action of the outer lip or scoop at the beginning of the arc of action tended to impair the efficiency of the wheel. It will be seen that if the arc of action is large enough the same effect will take place at the end of the arc of action, as well as at the beginning. If, therefore, the speed is increased to such an extent as to allow this to occur, there will be a further cause of loss of efficiency at high speeds.

It is estimated that the efficiency would not suffer diminution from this latter cause until the velocity reaches a value of 800 revolutions per minute with the 175 foot head or a value of 900 revolutions per minute with the 235 foot head. It will be noticed on reference to Table IV that the discrepancy between the theo-

retical and actual efficiencies shows a marked increase as the velocity approaches those respective speeds.

It may be remarked here that for constant dimensions of jet and bucket, as the diameter of the wheel is increased, the angle subtended by the arc of action will be diminished. With larger wheels, therefore, the departure of the cutting edge from the position of perpendicularity to the line of the jet will be less and the efficiency may reasonably be expected to be found greater.

In addition to the trials quoted and compared with the theoretical results, trials were also made with the small one-half inch nozzle. Complete tables of all the results obtained are given.

I.—NOZZLE .5277 INCHES DIAMETER.

(*a*) Pressure 50 pounds per square inch.
Equivalent head = 115 feet.
Discharge = 45 gallons per minute.

Speed	Horsepower	Efficiency
252	.79	50.7
322	.76	48.5
398	.93	59.1
400	.86	57.0
407	.84	53.5
438	.87	56.7
450	.94	59.9
497	.96	62.8
506	.94	60.4
545	.95	60.6
551	.95	61.0
565	.84	55.7
585	.76	47.3
588	.83	52.6
625	.91	55.7
638	.91	58.3
665	.83	52.2

(*b*) Pressure 75 pounds per square inch.
Equivalent head = 175 feet.
Discharge = 53 gallons per minute.

Speed	Horsepower	Efficiency
345	1.38	49.8
409	1.52	54.9
477	1.68	60.7
523	1.68	61.4
582	1.80	64.7
594	1.79	65.8
632	1.75	64.4
632	1.76	63.1
672	1.78	64.1
677	1.56	55.3
725	1.63	58.3
726	1.65	59.6
737	1.61	59.7
768	1.55	55.1
779	1.57	57.0
847	1.40	51 2
879	1.31	47.7

(*c*) Pressure 100 pounds per square inch.
Equivalent head = 235 feet.
Discharge = 63 gallons per minute.

Speed	Horsepower	Efficiency
276	1.70	37.9
306	1.85	41.2
345	1.98	44.4
387	1.90	44.5
459	2.22	49.7
470	2.36	52.8
541	2.52	56.0
605	2.67	60.0
644	2.80	63.2
698	2.76	64.0
760	2.96	65.0
834	2.65	59.5
858	2.78	61.8
914	2.76	58.6
939	2.76	57.9

(*d*) Pressure 125 pounds per square inch.
Equivalent head = 290 feet.
Discharge = 70 gallons per minute.

Speed	Horsepower	Efficiency
494	3.25	52.0
536	3.32	53.6
592	3.50	57.5
664	3.79	62.1
702	3.83	63.3
765	4.00	65.2
813	3.89	62.8
867	3 93	64.8
918	3.95	64.0

II.—NOZZLE .7532 INCHES DIAMETER.

(*a*) Pressure 75 pounds per square inch.
Equivalent head = 175 feet.
Discharge = 120 gallons per minute.

Speed	Horsepower	Efficiency
402	3.68	58 5
501	4.10	65 0
618	4.34	68 8
675	4.34	68.9
750	4.33	68.7
770	4.30	67 7

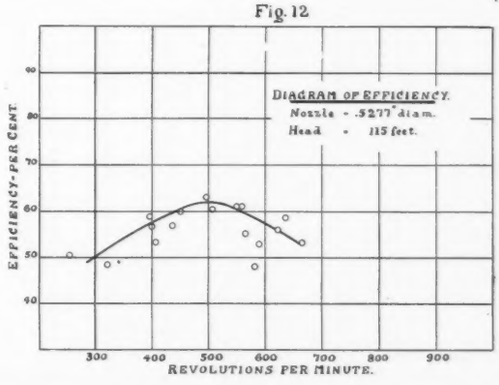
(*b*) Pressure 100 pounds per square inch.
Equivalent head = 235 feet.
Discharge = 138 gallons per minute.

Speed	Horsepower	Efficiency
370	4 82	49.4
371	4.86	50.0
475	5.67	58 4
515	5 95	60.7
588	6.20	63 9
654	6.60	67.8
698	6.66	68.6
756	6.88	70.8
815	6.72	69.3
911	6.35	65.6

The results given in the foregoing tables are represented graphically in figures 12–17.

In connection with the above results it is interesting and important to notice that the highest actual efficiency appears at a

Fig. 12

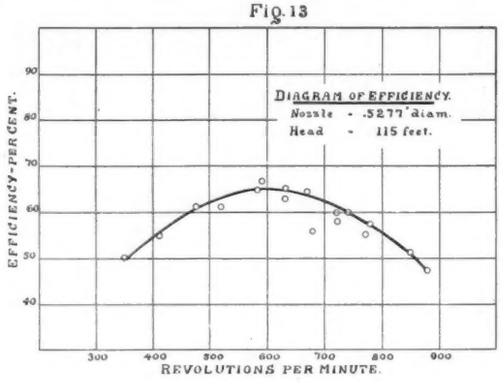


speed which is about .9 of that which theoretically should give the maximum efficiency.

A most important difference between an impulse water wheel and a turbine of either the impulse or pressure type is that the construction of the latter allows a larger area of water to be applied to the wheel for the same dimensions of wheel. In the turbine the wetted surfaces bear a much larger proportion to the size of the wheel than in an impulse wheel, and those surfaces in the turbine are constantly in action, while in the impulse wheel

their action is intermittent. When the head of water is small a correspondingly large quantity has to be used to give a required horsepower, and in this case the turbine has the advantage of passing a much larger quantity than the impulse wheel. When the head is very large this feature of the turbine becomes a dis-

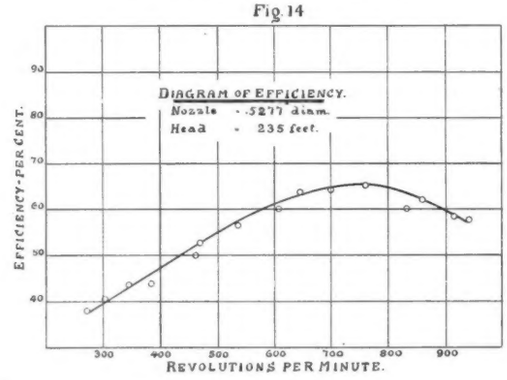
Fig. 13



advantage, as it becomes a difficult problem to curtail the total discharge of water so that the total power developed may be handled without mechanical inconvenience by the working parts of the motor.

For a given area of outlet the horsepower of the issuing stream varies as $h^{\frac{3}{2}}$. To illustrate this the horsepower of a stream one

Fig. 14



inch in diameter is given in the following table for a series of heads and also the number of such jets which would have to be applied to aggregate 1000 horsepower.

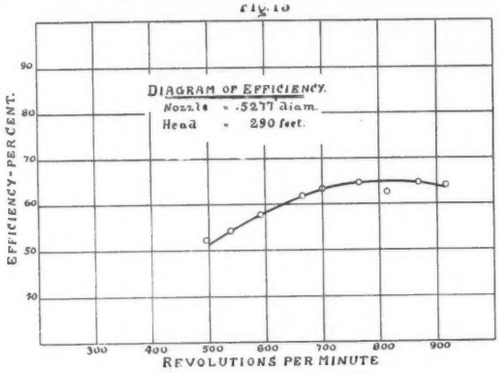
TABLE V.

Head	Horsepower	Jets to give 1000 horsepower
100	4.96	202
200	14.02	72
300	25.75	39
400	39.65	26
500	55.41	18
600	72.84	14
700	91.79	11
800	112.15	9
900	133.82	8
1000	156.73	7
1100	180.82	6
1200	206.03	5
1300	232.31	5
1400	259.63	4
1500	287.94	4
1600	317.21	3½
1700	347.40	3
1800	378 50	3
1900	410 48	2½
2000	443.31	2½

In order to develop considerable power with a comparatively small head, using an impulse wheel, one of two things must be done; either the area of the nozzle and consequently that of the vanes must be made very large, which is only practicable to a limited extent, or else the number of nozzles and wheels must be multiplied. Thus the use of impulse wheels under small heads involves a large amount of machinery for the power obtained.

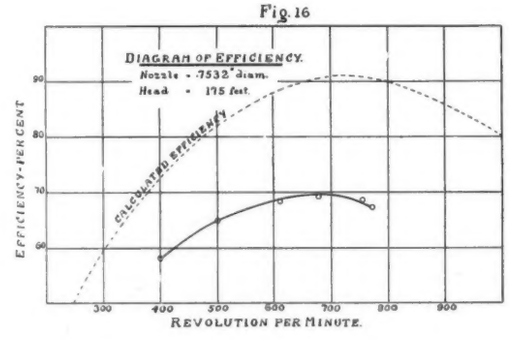
On the other hand, the impulse wheel has many points in its

Fig. 15



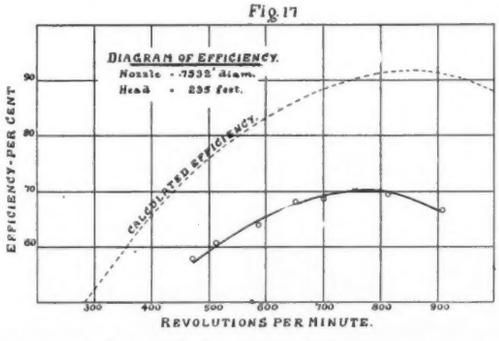
favor, chief among which is its simplicity of construction, which leads directly to the absence of mishaps and to ease of maintenance. The bearings are simple, being merely those on the horizontal shaft, in such a position as to be easily got at when necessary to make any repairs or adjustments. There are no bearings running under water; and the bearings are not subject to any other reaction than that due to the useful effort of the water

Fig. 16



on the wheel; no difficulty is met with corresponding to that of balancing the static pressure of the water on a turbine, which becomes such an important problem when large heads are being used. The impulse wheel has no water tight joints, as there is no water pressure to be maintained among the working parts. The mechanism also does not contain any parts which are likely to work loose or otherwise become deranged and so lead to trouble.

Fig. 17



Another good feature is the absence of passages in the working parts of the motor, which would be liable to become choked by debris carried through by the water. Once through the orifice the water has a perfectly clear and open course untii it falls into the tail race.

It is an easy matter in designing an impulse motor to arrange the diameter of the wheel so as to give a desired speed of rotation

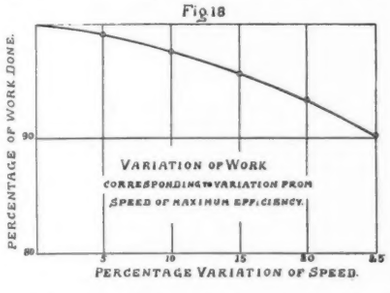
under an available head with the most efficient results. Small departures from this speed do not affect the efficiency to any great extent, as may be judged from an examination of the tabulated results. The following table is compiled to show the percentage loss of output of work due to a subsequent departure from the prearranged speed. This is illustrated graphically in figure 18.

TABLE VI.

Percentage. Increase or Decrease of Speed.	Percentage. Decrease of Output of Work.
5	¾
10	2¼
15	4½
20	6¾
25	9¾

An important point in determining the practical usefulness of water motors is their adaptability to be run with a fair degree of efficiency under a fraction of the full load. This state of things is generally liable to occur either intermittently, as where a number of loads are being continually put on and off the mechanism driven by the motor, or periodically, as where for portions of a day or week or year the work required from the motor is heavier than at other times.

Fig 18



Three methods will be mentioned which are employed to vary the output of work from the wheel.

It was mentioned that three nozzle tips of different sizes were supplied with the wheel with which the tests were made. By changing these the quantity of water discharged under a given pressure can be varied as the area of the orifice. The power of the jet will consequently vary in the same ratio; and so any change of load which can be anticipated and will last for a considerable period can be provided for.

The changing of the nozzle tips need not be a very difficult operation. It is, however, a very inconvenient plan to have to resort to in order to regulate the output of power from the wheel.

These wheels are sometimes built with several nozzles placed at intervals round the periphery of the wheel. When this is the case the power can be reduced by shutting off the stream from one or more of the nozzles.

The third method is to employ a valve or gate in the supply pipe which can be shut off to any desired extent by hand or by some automatic regulating machinery. This method is almost always necessarily employed in addition to those aforementioned. It will be noticed that the effect of the valve to reduce the power is reached by throttling the water as it passes the gate, thus reducing the pressure of the water as it reaches the orifice and consequently reducing also the discharge. It need hardly be pointed out that there is a great loss of efficiency when the motor is running under a light load, as the pressure energy which is not required to drive the machine is all absorbed without useful effect in the resistance of the partially closed valve.

An idea of the actual efficiency reached can be gained from a consideration of the foregoing results, obtained for the small nozzle, for the range of heads from 120 to 300 feet. In calculating the efficiencies previously given, the available work was calculated on the assumption that the pressure under which the test was made was the total pressure available. But if that pressnre is not the total available pressure, as when the pressure is reduced by throttling from 125 to 100 or 75 pounds per square inch, then the total available work must be considered to be the product of the weight of water used and the head equivalent to the total available pressure before any throttling took place.

Proceeding in this way, and using the amounts of work done obtained in the trials for the various heads, but considering the energy available in every case to be that due to a pressure of 125 pounds per square inch, gives results as follows:

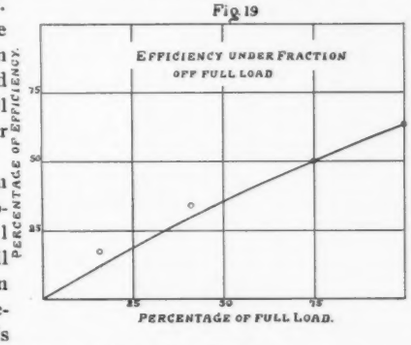
TABLE VII.

Pressure	Load	Efficiency
125	Full	65 per cent.
100	.75	50 " "
75	.40	33 " "
50	.17	about 18 " "

This is illustrated in figure 19.

Besides the fact that a large amount of energy is wasted in the throttling in the pipe, a further cause of loss of efficiency under a light load exists in the fact that the motor is probably working under unfavorable conditions of pressure and velocity. In general it is desirable to keep the velocity constant, although the work done may vary. This means that if the motor is designed to run at the most efficient speed under full pressure, it will exceed the best speed for lower heads.

Fig 19



It will thus be seen that the efficiency obtained on the total expenditure of water will be considerably less than that indicated by the previous tables if there is any considerable variation in the load put on the motor.

In the preceeding remarks an attempt has been made to describe and discuss the action of impulse water wheels, and more particularly of the wheel on which the experiments described were carried out; the question of efficiency has been illustrated and examined, and the advantages and disadvantagas connected with the use of such a system have been pointed out. It is hoped that these notes may throw some light on this interesting and important subject.

The writer wishes to express his indebtedness to Professor Bovey for his kind co-operation in allowing the use of apparatus and every facility for carrying out the experiments at McGill University, and also to Mr. Withycombe for useful advice and assistance with regard to many practical details connected with the trials.

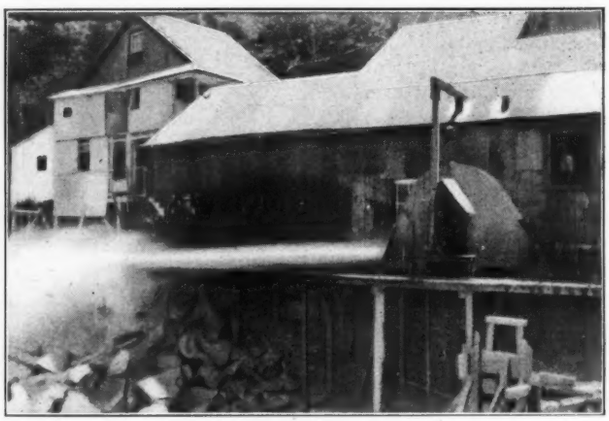
The preceeding paper by Mr. J. T. Farmer, unlike most papers on this subject that have appeared from time to time, contains some very valuable considerations; but, unfortunately, as is the case almost without exception, broad conclusions as to what bucket curves will do under greatly varying conditions are drawn from a few experiments on one water wheel under rather limited conditions.

Much money and gray matter has been expended in the attempt to attain "true hydraulic curves" in bucket surfaces to produce a superior efficiency, whereas the greatest losses are constantly under the operators eye in the nozzle, gate valve or discharge pit.

It should be the policy of the manufacturers of impulse wheels to construct the best possible wheel to meet a certain set of predetermined conditions, and it is no more possible to attain best efficiency from a wheel when these conditions are varied than with a centrifugal pump, steam engine or induction motor operating under radically different conditions from those for which it was designed. On the other hand, there is a constant demand for water wheels where the pressure, speed and load are not predetermined, and such a wheel Mr. Farmer has probably used for his experiments; that it was of extremely early construction is clearly shown by the design as illustrated in Figure 1.

Mr. Farmer has correctly estimated most of the printed matter on impulse whee s when he says that "No attempt seems to have been made to consider to what extent known and observable phenomena may modify theoretical conditions." The reason for this is that it is so hard to collect the great quantity of "known and observable phenomena" necessary to conclusions of any value, and so easy to theorize. Thus, one manufacturer finds an old Pelton bucket, worn on the back, at one of the best known power plants in the state, and immediately jumps at the conclusion, and publishes broadcast, that the concave surfaces of the bucket in front of it were not of the proper curvature, and therefore did the damage and must lose a large percentage of power; also, that this power could be saved by cutting out the front of the bucket, which, note, will therefore not catch this portion of the stream of water at all, and which will escape without impact.

The result is as shown in the accompanying picture, where one of these open front bucket wheels is running at correct speed with nozzle in correct position, and the consequence is that the poor



old Pelton wheels are again patiently grinding out power at the old stand and giving better results than any of the other numerous types tried in the meantime. A more careful inspection would have shown that the wearing on the back was caused by an entirely separate set of conditions independent in every way of any bucket curves, and attributable to the regulating device which was saving water of incalculable value at periods of partial load.

To attain the maximum commercial efficiency from any set of natural hydraulic conditions of pressure and water quantity, it is essential—

(1) That the water be conveyed through a pipe and terminal connections, which, while not being too costly, will deliver the required quantity of water with the least fractional loss.

(2) That the water wheel buckets be of such shape and so arranged that the impacting water be received by them and its velocity reduced to zero with the least expenditure of frictional resistance and of eddy currents.

(3) That in leaving the bucket, or rather in the bucket leaving it, a free air passage be left for the next bucket and that the water properly discharge from this position through the tail race.

It is not essential in order to meet the second condition that the bucket wedge be perpendicular to the stream at all times during its active path, so long as the various curves over which the water flows are of the proper shape.

An inspection of Table IV of Mr. Farmer's article shows a great discrepancy in the calculated and actually attained efficiency, but not by any means entirely due to bucket curves as Mr. Farmer, and, in fact, most other writers, have assumed. The air friction in this motor and the shape of the case are probably factors of some considerable importance, and are passed by as negligible. The nozzle setting, as shown in Figure 1, is entirely too high, and the bearing friction must accouut for several per cent.

In spite of the fact that the bucket is of an old pattern and today greatly improved, the writer ventures to say that bucket curves are not responsible for more than 10 to 12 per cent. of the difference at most. In a properly designed bucket or vane the outer lip should not be blunt, and certainly there is no excuse for the spattering condition shown in Figure 8, nor could the deflected condition shown in Figure 9 be possible.

Figures 10 and 11 show a stream much too large for the bucket, and a condition of discharge that does not and cannot occur under running conditions.

In regard to Mr. Farmer's suggestions on the cause of the loss, we do not agree with him, as we have frequently obtained as high efficiencies on wheels where the arc of active bucket path was forty-five degrees as where it was ten degrees. The important point is, not the perpendicularity of the wedge, but to take all of velocity—*i. e.*, energy—out of the water with the least loss—accomplish this as you may. The Berry bucket wedge remains perpendicular throughout its path, but unless this bucket has the front lip it cannot approach many other types for efficiency.

One might infer that Mr. Farmer's experiments show the uselessness of the front lip. This, however, is not the case, as an inspection of the bucket illustrations shows it to be a very important function in the line of water travel, and, while not entirely correct, it is a fact that it does fill, with great increase of efficiency, a very important gap. The first wheels built by the manufacturer before referred to, had buckets without front lips, this for the purpose of preventing the so-called spattering and deflecting action caused by the front lip. The best efficiency obtained was much under 50 per cent., and they were, after all other resources had been exhausted, entirely replaced by Pelton wheels, which, with the same nozzles, gates and tail races, gave over 80 per cent efficiency.

As to the action of the entering lip, if all of the water of the jet that theoretically is apportioned to each bucket is caught by its bucket, and the energy taken out in accordance with the preliminary condition (No. 2) for attainment of maximum efficiency, then we will get the best possible result. This water cannot all be caught without a front of some kind in the bucket, and this front should be made of such shape and so finished that there is no more loss on it than on the splitting wedge in the center of the bucket. There cannot possibly be any loss in a properly designed wheel, due to spattering on the front on leaving the stream, because this would mean that there was some water escaping through without even touching the buckets.

The fact that the loss increases at high speeds is probably not due to this spattering so much as to the water escaping through without any impact at all.

This also makes the deductions given in table VI partially incorrect, as the decrease in output of work should be and is greater for 25 per cent. over speed than 25 per cent. under speed.

In regard to speed or power output control by the methods given, no mention is made of deflecting nozzles, of stream deflectors, of cut-offs, or of regulating nozzles, each of which has its own particular field of usefulness.

Table VII is somewhat misleading, as one would infer that when the pressure was cut down to fifty pounds per square inch from 125 pounds, 17 per cent. of full load could be obtained from the wheel at the correct speed for 125 pounds pressure; whereas, strange as it may seem, a negative result would be obtained instead, that is, more power would have to be put into the wheel to drive it up to the correct speed than if the gate was shut entirely and no water flowing.

Mr. Farmer deserves much credit for the care with which he has studied his subject, and it is to be regretted that his experiments were not over a broader field. Professor Carpenter, of Sibley College, Cornell University, has devoted much attention to the subject, and on Pelton motors—however, of much more recent manufacture than that experimented on by Mr. Farmer—has attained an efficiency of 88 per cent., and has proved this later form of the Pelton bucket to be the best so far attained.

GEORGE J. HENRY, JR.

San Francisco, February 26, 1902.

LOMBARD GOVERNORS IN SANTA ANA STATION.

AS one studies in these times of rapid progress the installations of great water power plants for generating electricity, he naturally becomes interested in the manner in which certain obstacles have to be overcome to place the plant on a practical commercial basis. One of the obstacles which has indeed puzzled many an inventor and engineer is the question of speed regulation. When once this question is practically solved then a great many other trying difficulties straighten themselves out.

At the time the Southern California Power Company had to face this problem of speed regulation, some three years ago, it had several novel and untried conditions to work against. As is well known in regard to this plant, at the time of its being built it was to have the longest transmission line then known and under

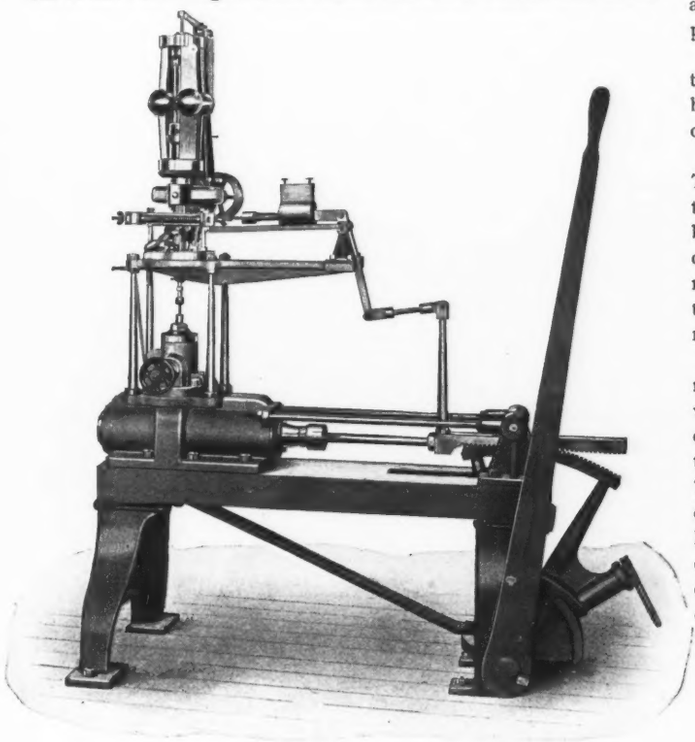


FIG. 1.

a very high voltage, and its wheels were to work under a head of several hundred feet. Tangential water wheels were to be used and to be fed by a pipe some 2000 feet long, and the speed regulation was to be obtained by the use of a deflecting nozzle throwing water on or off the wheel. As it was thought necessary to have the guaranteed speed regulation "less than 2 per cent. variation from normal speed on instantaneous changes of half the load. Speed to back to normal in five seconds," some idea of the problem may be grasped.

Formerly a governor had not been made which would give as accurate a speed regulation working in connection with an impulse wheel under high head. To meet these special requirements the Lombard Governor Company of Boston designed what is known as its "Type F" governor. Four of these governors were installed and placed in the plant in competition with another make of specially designed governor, and they were so successful that all of the Pelton wheels in the station referred to are now equipped with the Lombard governors.

The speed regulation has even exceeded what was sought for, and Mr. O. H. Ensign, superintendent of the company, says that "for simplicity, small number of parts, close regulation and absolutely relieving the mind of the attendant of the matter of speed during short circuits, sudden changes and sudden overloads, or blowing of fuses, it is the most perfect device of its kind I have ever seen, and, indeed, there is nothing further to be desired."

Figure 1 illustrates the "Type F" governor that was used at the Santa Ana power house of the Southern California Power Company. On examination of the cut quite a clear idea of the governor may be gleaned. The water cylinder, shown by the piston rod projecting through a gland at one end, is mounted on a cast-iron bed, which is supported in turn by two cast-iron legs. The piston rod of the cylinder is attached rigidly to a rack which moves a gear sector which is keyed to the main governor shaft. This latter shaft is attached direct by means of a coupling not shown on cut, but directly in back of the governor leg, to the deflecting nozzle. In case the operator wishes to throw out the governor he lifts the small clutch handle shown on sector and works the large hand lever.

Above the hydraulic cylinder is noticed the regulating valve, and higher still the governor top table, with the governor balls, puliey, dash-pot connections, etc.

Water is taken from the feeder pipe and is made to enter below the bed of the governor directly in under the large port that can be seen cast on the cylinder. The water is exhausted on the opposite side of cylinder and piped to the tail race.

The action of the governor as stated in a few words is as follows: The governor balls are made to revolve by means of a drive from the main water wheel shaft to the governor top pulley, and these balls move a small valve stem as they are thrown in or out by centrifugal force. This valve stem works a triple valve in the regulating valve case, which ports water under pressure, and by the position of this valve the main piston, and thus the deflecting nozzle is brought to the proper position.

The course of the water is very direct. It starts through the regulating valve, then through ports to the cylinder and does work on the piston and is then exhausted. As this water acts directly on the nicely adjusted triple valve, it can be seen that the water should be practically clear of sediment and the like. The water at the Southern California power station was open to objections on this point, and the difficulty was overcome by Mr. Ensign, who devised a settling box which very successfully eliminates the trouble. The one great point in which this governor excels others, is its ability to bring the valve back on the center at the proper time, and to do away entirely with what is known as racing.

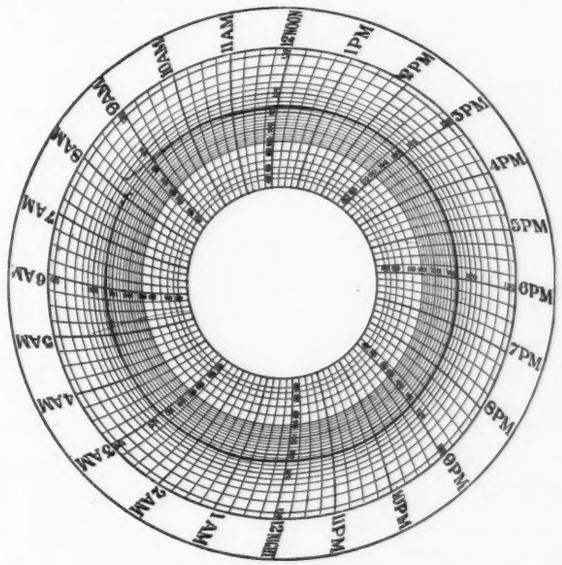


FIG. 2.

Figure 2 shows a Bristol recording volt meter chart, which exhibits the extremely constant voltage that is obtained at the plant in question.

The "Type F" governor is the smallest type of governor manufactured by the Lombard Governor Company of Boston, which also builds governors working under oil as well as flume pressure, for any size of tangential wheel or turbine under any head.

ELECTRIC POWER TRANSMISSION IN UTAH.*

DURING the year 1891 the Utah Light and Power Company expended over $100,000 in reconstructing its distributing system. A larger amount will be spent during the present year, and when the improvements outlined are completed the company will be in a position to sell more than twice as much power as it does at present, and to give a service that will be absolutely reliable. The system now owned and operated comprises three water power plants, eighty miles of high tension transmission lines, and also light and power distribution apparatus in and near Salt Lake City and Ogden, together with one substation for supplying the Salt Lake City street railroad and some reserve steam plants. Probably in no other city of its size in the United States has electrically transmitted power reached such a relatively important place in the community as at Salt Lake City. The development not only started early, but has been very rapid. The snow-fed mountain streams of the Wasatch range on the east side of Salt Lake valley offered opportunities to the hydraulic and electrical engineer which have not been neglected.

To understand the situation, a short historical review will be necessary. Although coal is not excessively high, being from $2.50 a ton for slack to $4.50 for the best lump, the proximity of water power with high head to such a market as Salt Lake City and its surrounding smelters and other power consuming industries, led to the erection several years ago of three different water-power plants by three different companies. The Big Cottonwood Company completed a plant† in Big Cottonwood canyon, fourteen miles southwest of Salt Lake, in June, 1896. The Pioneer Power Company started its plant‡ in Ogden canyon, near Ogden, thirty-seven miles from Salt Lake, in July, 1897. The Utah Light and Power Company, in 1897, built a plant in the Big Cottonwood canyon for transmitting power for the Salt Lake City Railroad. The first two of these plants finally became consolidated with the electric lighting interests of Salt Lake, and are now operated, together with the third plant, as parts of one complete and comprehensive system, covering a district extending north and south about sixty miles, including Ogden, Salt Lake and a district thirteen miles south of the latter place, containing some large smelters.

The Ogden power house has an electrical installation of 5000 horsepower at present. The company is about to commence the construction of a large dam in the Ogden canyon, which will form a storage reservoir for the flood waters. The reservoir so constructed will have a total capacity of about 2,000,000,000 cubic feet of water, and will be used for both irrigating and power purposes. When this reservoir is constructed the Ogden power house will have a maximum capacity of 8500 horsepower. The plant will then be completed as it was originally designed, and will be the finest in the inter-mountain region. When this dam is complete the transmission line from Ogden to Salt Lake will be duplicated, in order to insure absolute immunity from breakdown.

The Big Cottonwood power houses have a maximum capacity of 2000 horsepower each. Several improvements are contemplated on the plants in this canyon, which, while not increasing the total power to any great extent, will render the plants absolutely reliable under all the varying conditions that have been found to occur in the Cottonwood canyon.

The power is being transmitted from Ogden at 16,000 volts, and from the Cottonwood canyon at 12,000 volts. Changes are now being carried out, and, when these are completed, the whole transmission system will be operated at 25,000 volts.

In Salt Lake City the company has now three reserve steam plants of an aggregate capacity of 2000 horsepower. These plants are used in case of emergency and to supply any shortage of power caused by a breakdown or other accident at the power houses in the canyons.

The company's engineers are now designing an entirely new station to be built in the west end of the city. It will be the most modern and economical generating and distributing station that can be built. It will be used, first, as a receiving station for all high tension transmission circuits; second, as a distributing station for the light, power and street railway circuits in Salt Lake, and, third, as an auxiliary generating station, to be used in case of breakdown of any of the water power plants or transmission lines. Provision will also be made for the erection of a storage battery, which will be used for regulating and for emergency.

*From the *Western Electrician*, Volume XXX, page 81, February 1, 1902.
†Described in THE JOURNAL, Volume III, page 21, August, 1896.
‡*Ibid*, Volume V, page 109, March, 1898.

"PROTECTIVE DEVICES."

PROTECTIVE devices is the title of a new S. K. C. System Bulletin, No. 124. This bulletin describes the S. K. C. switchboard and pole line fusible cut-outs, including the 30-000-volt "Ball Fuse" and the Type "F" high capacity fuse. A combined oil switch and circuit breaker switch, the circuit breaker of the slide type, each break of which is provided with an arc rupturing shutter, are also illustrated and described. The S. K. C. secondary protector, lighting arrester, ground detectors, etc., are other subjects discussed in this publication.

The bulletin is perfectly printed, beautifully illustrated and is a comprehensive treatise of the subject covered. It is published by the Stanley Electric Manufacturing Company of Pittsfield, Mass., and will be sent gratuitously to those interested upon request.

A NEW LOMBARD CATALOG.

THE Lombard Governor Company, of Boston, Mass., has just issued a very neat and attractive catalog illustrating its different types of water wheel and steam engine governors and allied appliances. As the Lombard Governor Company has under control by its governors over 300,000 horsepower of water wheels in this country alone, some idea may be had of the rapid strides first-class speed regulation has made within a comparatively short time.

From this fact alone the new catalog is well worth the reading, as it shows how generally the best results have been sought after in water wheel plants by prominent engineers the country over. Concise and accurate descriptions of all types of Lombard governors are given, while several good photographic illustrations of modern plants with tables are included within its covers.

THE "SPERRY" BATTERY ENJOINED.

JUDGE COXE of the United States Circuit Court rendered a decision on December 20, 1901, again sustaining the validity of the Brush storage battery patent, and granting an injunction against the National Battery Company and the American Bicycle Company enjoining them from the further manufacture and sale of the so-called "Sperry" battery.

The Electric Storage Battery Company, the owners of the Brush patent, has announced its purpose to vigorously prosecute all manufacturers and users of infringing batteries, and has published notice to all makers and users of infringing batteries to that effect.

The "Inductor Type of Generator," a technical treatise by Edward Heitmann, which ran as a serial in the *Electrical World and Engineer*, issues of October 5th, 12th and 19th, has been reprinted with illustrations in pamphlet form, making bulletin No. 123 of the S. K. C. System. A copy of this may be had by addressing the Stanley Electric Manufacturing Company, Pittsfield, Mass.

PERSONAL.

Mr. Robert McF. Doble, of San Francisco, consulting engineer, is in British Columbia engaged in the examination of hydro-electric transmission projects for the city of Vancouver and vicinity.

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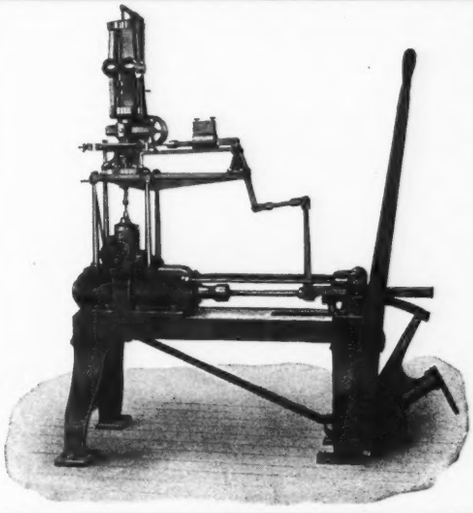

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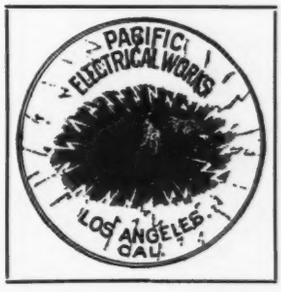

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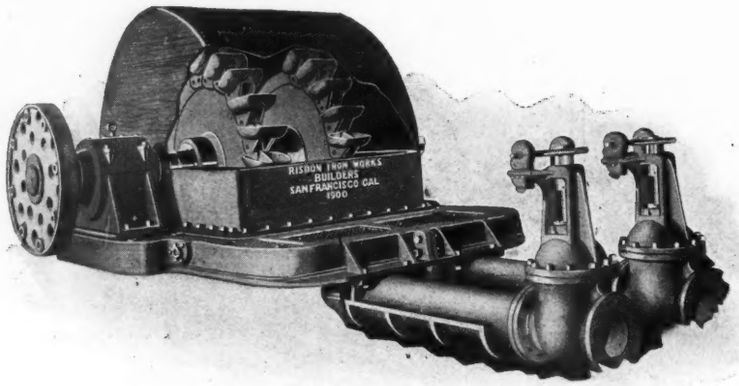

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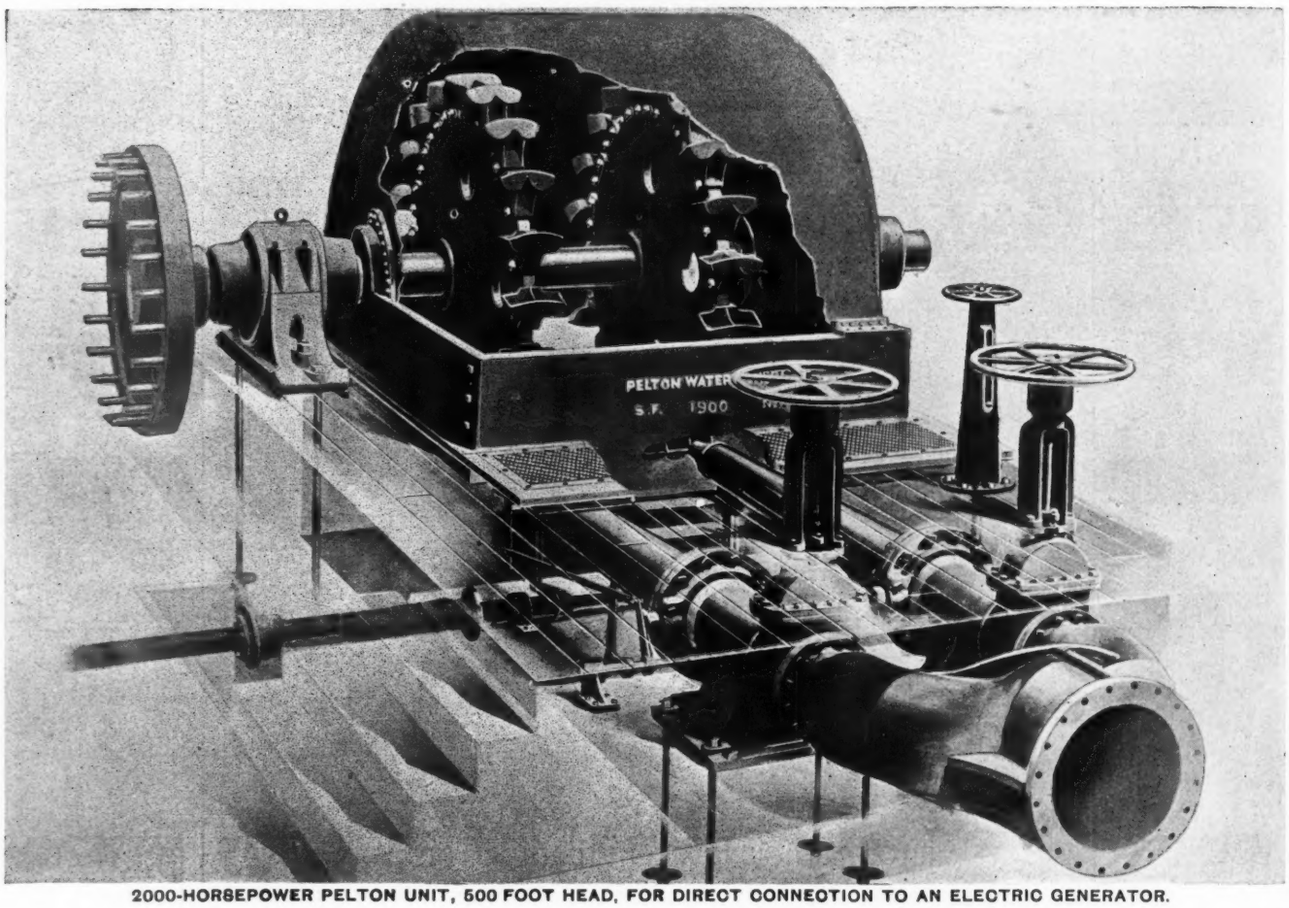

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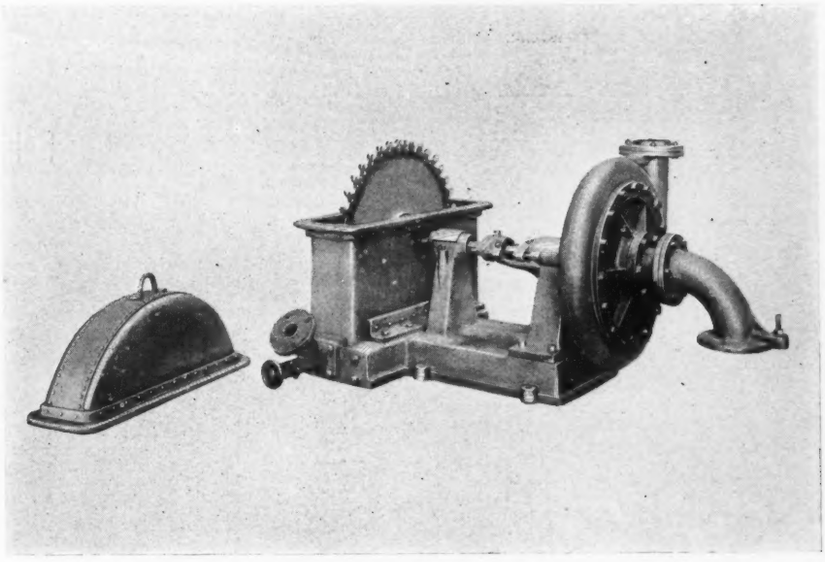

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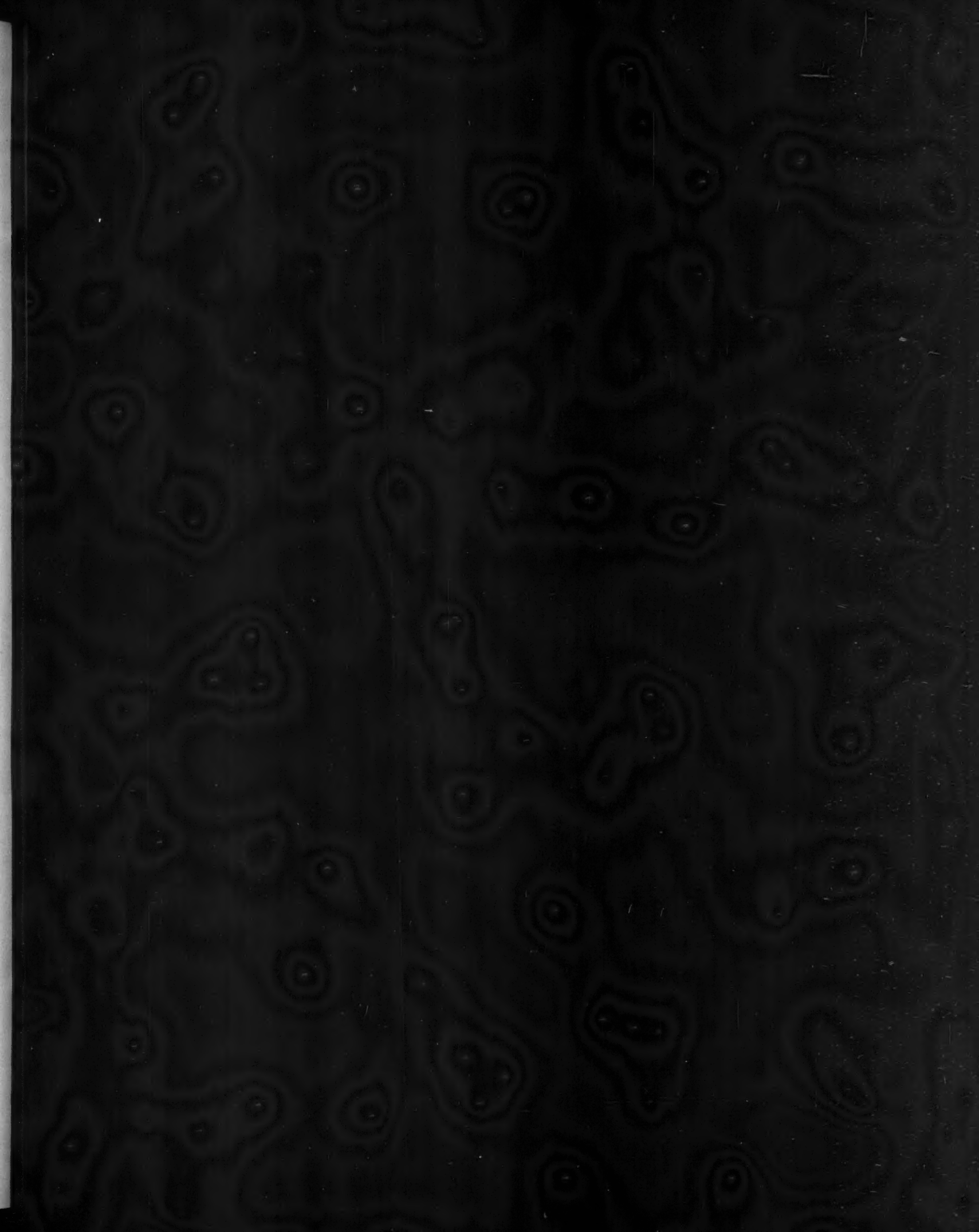

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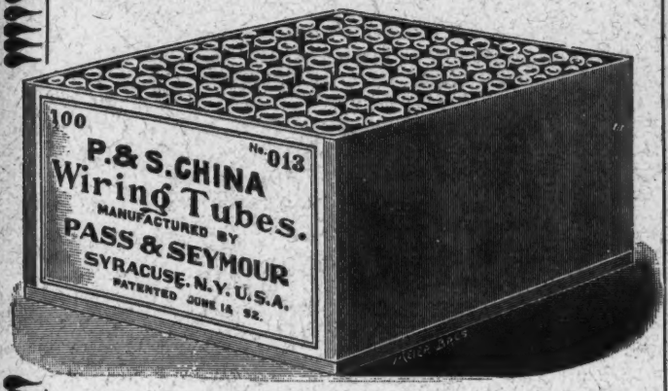

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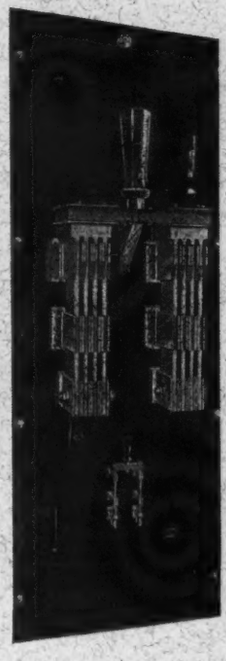

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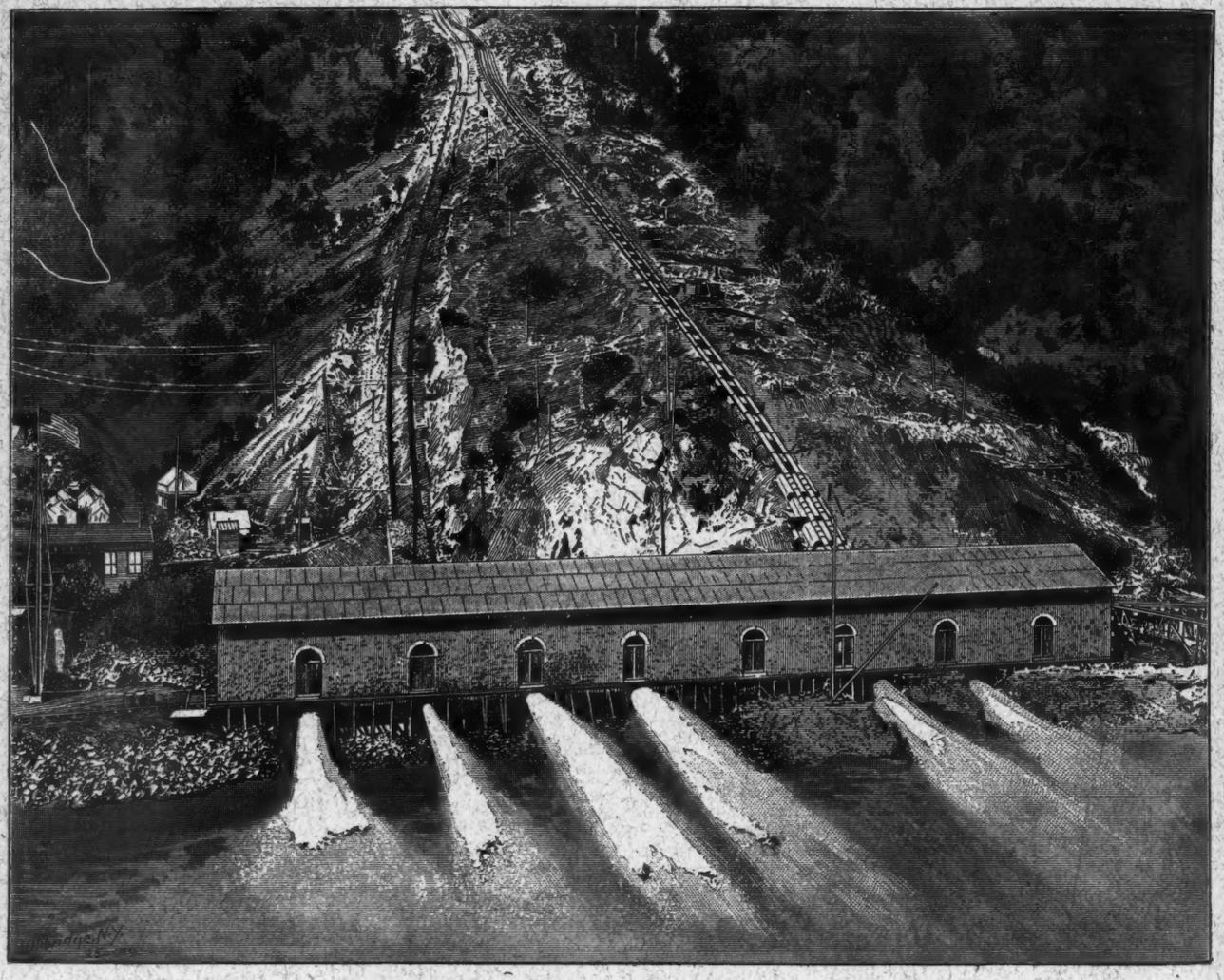

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